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A quarterly paper devoted to the sugar interests of Hawaii, and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

JANUARY TO DECEMBER

THE HAWAIIAN PLANTERS' RECORD

VOL. XXXIII

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Short Cropping at Pioneer*

By R. M. Allen

Realizing that questionnaires are sometimes a nuisance, the writer has refrained from requesting others to answer numerous questions on the subject of short cropping and has decided to discuss it as it appears to us at Pioneer.

I hope that the problems that we are up against and which will be briefly enumerated in this paper, will invite discussion by those interested and that the subject can be covered more fully than had a chosen few been requested to fill out a lengthy questionnaire.

We have always had "short ratoons". In fact, I think it has always been the custom on most plantations to harvest certain fields in November and December, and harvest these again a year from the following June and July. These so-called "short ratoons" are actually from 16 to 18 months old, just as old, in fact, as many of our so-called "long ratoons". What we are primarily interested in now are the fields harvested between January and May.

At Pioneer the harvesting schedule in general usually called for the fields that were to be short ratooned to come off first, followed by the fields to be planted and harvested two years hence, and lastly the fields to be long ratooned. Our short cropping policies do not affect the first two classes of fields, but have a decided effect on the early harvested fields that would ordinarily be long ratoons. In the past we have given a field harvested in March practically no attention, except sufficient water to keep it alive until June, July, or even as late as August and September. This field would then be harvested in March and April and would apparently be from 24 to 26 months old. Actually, however, considering the fact that it had only been kept alive for from 3 to 6 months after it was cut it was only from 17 to 20 months old. Under our short cropping schedules this same field would be fertilized and irrigated immediately after it was cut, and

* Presented at seventh annual meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 15, 1928.

would continue to get the same intensive treatment that had always been given the old so-called short ratoons and would be harvested again in July or August of the following year, at an actual age of 17 months. By following this practice all of the idle time, which occurred under the old system, has been eliminated and the land involved has been producing continuously. Figuring that our lands are capable of producing say .35 of a ton of sugar per acre per month, an idle period of 4 months, although it may not represent a loss of 1.40 tons of sugar, does result in some definite loss.

From this standpoint the "short cropping" system, or "cut and grow system" or "intensive cropping system" has appealed to us and we have extended materially our area of short ratoons. In order to handle this additional area it is necessary to do one of two things: either add to the labor supply or slow up harvesting. In the writer's opinion this can best be accomplished by slowing up on the harvesting and using the men that would normally be in the harvesting field, in the ratoons. In fact it may be advisable to stop harvesting two or three times during the season and clean up, fertilize and irrigate the ratoon fields. This year at Pioneer we shut down for three weeks in June, and the probabilities are that we will do this twice during the next season: once in March and once in June or July.

The result will be, of course, that we will not finish grinding until late September or even October, in some cases, where we normally would be through by the latter part of June or the first of July. From the field man's standpoint this practice seems sound, and is, I believe, better than adding materially to the labor supply and creating jobs for them during the longer off-season that we used to have when we finished grinding early (June or July). However, before we can be sure we can carry this out year after year we must consult our mill engineers, as it means cutting the off-season available for repair work just about in half, and there is some question whether or not our mills can be reconditioned in this relatively short time. This is an important point to bear in mind when weighing the possibilities of the more intensive system of cropping, and our mill men should have a loud voice in the discussion which is taking place on this subject.

From the standpoint of irrigation, I believe that this system will result in a saving of water, in spite of the fact that there is an added area of small cane to care for during the entire year. This saving will result from the fact that there will always be a smaller area of big cane to irrigate during the dry months of June, July and August than there would have been under the two-year cropping system. Take for example a typical field harvested in April, 1928. Under our old system the schedule would call for the field to be harvested again in February, 1930, at an age of 22 months. Under our intensive cropping system we would plan to harvest it in September, 1929, at an age of 17 months. During the months of June, July and August under the former system we would be irrigating this field full blast in order to take full advantage of the second summer's growth; but as a short ratoon we would begin to ripen it in June and it would receive practically no water during July and August, 1929. The water would then be available for irrigating the young ratoons, and, of course, would serve a much larger acreage than had it been used in the big cane. Whether or not this saving will compensate for the larger acreage under cultivation is an open question.

Here at Pioneer we are up against the additional problem of fluming fields that are short cropped, and consequently harvested late. We have always figured that it was essential to finish fluming these fields before June, at which time our water shortage usually sets in. In our 1928 crop, we had a considerable acreage of short ratoons situated in our flume area, where we are short of water, and did not finish fluming there until August. The theory was when planning the crop that it would not take as much total water to flume these under the new system as it would to irrigate under the old system. We have gotten by with it, but it is necessary to hold off on the conclusions as we got unusually good water.

In considering yields under our short cropping system it is necessary to forget for a time the yield per acre and think in terms of tons of sugar per acre per month, and even this does not tell the entire story. Ten tons of sugar per acre sounds like a good yield (?) and 7 tons is considered a poor yield. However, if the former is from a field growing 24 months and the latter is from a field that has been growing only 17 months, both have produced a yield of .426 ton of sugar per acre per month. Over a period of years a condition such as this favors slightly the long crop, as the short crop has been started out and cut oftener than the long crop. However, a slightly larger yield, of say 8 tons per acre, which I believe is entirely possible in localities where a 10-ton long crop yield is possible, would yield .470 ton of sugar per acre per month and turn the tables in favor of the short crop. In 72 months, or a time equivalent to three long crops, the long crop would have yielded about 31 tons of sugar and the short crop about 34 tons.

All of this is pure theory and although some plantations may have conclusive evidence for or against short cropping, we at Pioneer are still in doubt and are extending the policy largely on the theoretical evidence in favor of it.

The average yield of sugar per acre at Pioneer of long and short ratoons for the past four crops is given in the following table:

	1925 Crop	1926 Crop	1927 Crop	1928 Crop
Long Ratoons	7.35	6.65	7.70	8.40
Short Ratoons	5.83	7.14	7.03	7.06

It should be explained here that the long ratoons of 1926 suffered considerable strike damage.

A little more light is thrown on the subject when the age of the various fields is considered. The average age and yield in tons of sugar per acre per month for the 1926, 1927 and 1928 crops are shown below:

	1926 Crop		1927 Crop		1928 Crop	
	Age	TS/A/M	Age	TS/A/M	Age	TS/A/M
Long Ratoons	22.27	.299	22.26	.346	23.66	.355
Short Ratoons	17.10	.419	18.93	.366	19.31	.366

The average yields in sugar per acre per month for plant, long and short ratoons for the four crops 1925, 1926, 1927 and 1928 are given below:

	Age	TS/A/M
Plant	21.59	.457
Long Ratoon	22.73	.332
Short Ratoon	18.49	.370
Grand Average	21.97	.368

There is another point in connection with this problem which should not be overlooked. Increasing the acreage of short ratoons means, of course, that a larger percentage of the total area is harvested each year, and the larger the acreage harvested the smaller the charge per acre for the fixed charges that go to make up the total cost of a crop.

A rough examination of the cost figures on several plantations shows that approximately 30 per cent of the total cost remains the same, regardless of the area harvested. In this 30 per cent is included office, management, taxes, water rent, general repairs, a certain portion of mill expenses, carpenter shop, machine shop, garage expenses and many other items with which we are all familiar. These charges are more or less fixed and remain practically the same whether we harvest, say 2500 acres or 2750 acres per crop. For the sake of argument, say, the total cost of a crop on a given plantation is $1,250,000. Thirty per cent of this is $375,000. On a normal crop of 2500 acres this represents a cost of $150 an acre. If 250 acres of short ratoons have been added and the total area increased to 2750 acres, the cost per acre would have been $136 or a difference of $14 on every acre in the crop. Assume a normal yield of 8 tons of sugar per acre and we see that the cost per ton of sugar would be reduced $1.75 a ton by simply increasing the area harvested.

The fallacy in this argument is, of course, the fact that the average yield would probably be reduced by the additional short ratoon area. Just how much a 10 per cent increase in short ratoon area will decrease the average yield it is too early to say definitely, but it is very probable that it will not be more than .25 of a ton of sugar per acre. If this is true the cost per ton for these fixed charges would in one case be $18.70 a ton, and in the other $17.20 a ton, or a difference of $1.50 a ton of sugar due to a 10 per cent additional area.

There is, of course, reason for argument on this point, but the writer firmly believes that, everything else being equal and discounting a reduction in yield due to the short ratoon area, a 10 per cent increase in area will result in a reduced cost of at least $1.00 a ton of sugar. This is, of course, a very strong argument in favor of the short ratoon theory and it will be interesting to see how the costs on the plantations that have extended their short ratoon area compare with previous years under the old system. It is very possible that by proper treatment many of our short cropped fields can be made to yield very nearly the same as the average yield of our long ratoons, in which event the above argument is strengthened.

The fertilization of our short ratooned fields presents another problem that must be carefully studied. Most of us are of the opinion that the last fertilization should be about a year before harvesting. This means that in the case of a field cut in April the first fertilization is in April or May and the last application of either nitrate of soda or sulphate of ammonia is given in July or August. According to all the growth figures available the rate of growth drops rapidly from this month on and there is some question whether a given amount of fertilizer applied at this time has the same value as the same amount applied in January or February, as would be the case in a long ratooned field.

We have noticed this year that our short cropped fields yellowed off early in the year and there is a possibility that we would have fared better if we had split our last fertilization and applied part of it in December or January, depending on an increased yield to make up for the poorer juices that might have resulted from the later application of fertilizer.

One of the serious problems in short cropping arises from the fact that fertilization in many of the fields must take place prior to or just following the tasseling period. There was a time when we thought a dose of fertilizer in August or September would decrease the amount of tasseling. Our experiences at Pioneer during the last few years have led us to believe that this is not the case. If anything, the contrary is true, and instead of forcing our fields out of tasseling we forced them into tasseling.

The question here is whether it is better to get all the fertilizer on early, within four or five months after the field is cut, and get the full advantage of the early summer's growth that the fields will have, or to spread out our fertilization in an attempt to keep the field growing during the cooler months.

The feeling is strong among those that are giving this matter thought, that the intensive cropping system will enable us to ratoon longer, due to the fact that the vitality of the stools is kept up during the entire life of the crop. Comparing this with the practice we used to follow at Pioneer, of hardly keeping our fields alive for three to six months after they were cut, there is little question but that this treatment weakened the stools and forced us to plant oftener than will be necessary under the new system. It will be fortunate if this proves to be true, for the success of our short cropping practice depends largely on the extra cost of starting the ratoons and harvesting oftener being offset by the ability to ratoon longer.

Summarizing the problem, I feel that there is strong evidence favoring a more intensive system of cropping. We still have a lot to learn as to the best method of handling this increased area, and the point wherein our profitable limit of increased production lies. We know that we can ripen our fields in from fifteen to seventeen months, and can materially increase our total production by extending our short ratoon area. Whether or not this increased production is profitable, remains to be seen, and the real test will come when the cost figures for crops containing this added area are available.

The Residual Effect of Nitrogen Salts Upon Drainage of Heavy Clay Soils

By W. T. McGeorge

In comparing the development of agriculture in humid and arid climates, that is, adequate and insufficient rainfall, longer lived soil fertility has been predominately associated with the former. Where artificial irrigation is practiced a more rapid deterioration of optimum growing environment in the soil takes place. Of

course, in climates where irrigation is necessary climatic conditions are often such as to have greatly changed the chemical nature of the soil, and this being little understood has served to lead the irrigation farmer more rapidly into pitfalls. Failure has on the whole been due to either an excessive saline content of the irrigation water, to a rise in water table from excessive irrigation and poor drainage or to the accumulation of salts from poor drainage alone. Under any one or all of these conditions it is only a matter of time until the salt content of the soil solution exceeds the limit of tolerance of the crop.

We have devoted considerable time and study to the problem of salt accumulation in our plantation lands and have definitely shown a number of cases where salt accumulation has injured and even completely prevented cane growth. On the other hand the physiological effect of salt upon the cane plant is only one phase of the problem and possibly a minor one at that. Changes in the chemical nature of the soil solution, especially where large amounts of soluble salts are involved, may result in an extremely undesirable mechanical condition. The soil may become relatively impermeable to water, difficult to till and often quite unproductive.

This latter phase of the salt or alkali problem has received much intensive study the past few years which has been of infinite profit to the irrigation farmer both in helping him to avoid the pitfalls of irrigation practice as well as to intelligently reclaim his mistakes. Briefly these investigations have shown soils to contain certain silicate compounds, components of clay, known as zeolites, possessing jelly-like properties, which lie at the very foundation of soil behavior, both physical and chemical. The basic character of this clay component largely determines the permeability of a soil, and this basic character is directly governed by the composition of the irrigation water or the nature of the chemical salts used in commercial fertilizers. Permeable or well-drained soils are predominantly lime soils and any practice which results in a disturbance of this condition will usually result disastrously for the farmer. Use of high sodium waters and continuous use of nitrate of soda are known examples. Once the soil reaches a state of low permeability some source of soluble lime is essential for its reclamation. Any reclamation program must needs involve some type of leaching, which, too, must be intelligently planned and followed out. When a soil has once become impermeable, salt water will move through it faster than fresh water. In fact the latter when applied to a saline soil will usually result in a "freezing up" and therefore a lower degree of permeability than formerly existed will follow. A logical procedure, therefore, for reclaiming an impermeable soil is to provide drainage and flood with water, either pump or fresh, to which a soluble lime salt has been added.

Few of our plantation soils are so completely impermeable as to make cropping impossible. On the other hand, we have large areas of heavy clay soils in which water movement is sufficiently poor as to greatly slow up drainage and often injure cane growth. Examination of soils from such areas has usually shown the lime which should predominate to have been in part displaced by other elements, notably, sodium and magnesium or hydrogen, the latter to form an acid soil. Notable accumulations of salt are also often found in these poorly drained areas.

The yields on many such fields are not sufficiently depressed as to warrant any drastic reclamation program which would require the abandonment of cropping for a period. But the question arises as to a plan looking toward a gradual improvement in fertility and drainage by slight modifications in methods of fertilization.

Of the nitrogen, phosphate and potash compounds used in commercial fertilizers the phosphates are usually good flocculants and work for better mechanical condition of the soil. The muriate and sulphate of potash too are not usually given to harmful residual properties. On the other hand, the residual effect of the nitrogen carriers does often notably influence the physical condition of the soil and therefore its ability to "take water." Of course, one logical procedure would be, as already stated, to add soluble calcium salts to the irrigation water if a change in fertilizer is objectionable. This would tend to balance the use of high sodium waters and to restore the calcium balance in the soil, thereby making for better permeability.

The continuous use of sodium nitrate in some arid districts has met with more or less disfavor. This, however, was previous to our knowledge of its effects upon the soil zeolites. Thus far we have no evidence that any such objectionable effect has followed its use here in the Islands. On the other hand, one would most logically suggest certain modifications for applying nitrate of soda to our heavy clay types with a view toward improving the mechanical condition of the soil. While it is definitely certain that substitution of nitrate of lime for nitrate of soda would make for rapid improvement in permeability the property of this material for rapidly absorbing moisture has caused much objection to its use.

The following experiments were conducted to gain information regarding the comparative effect of nitrate of lime, nitrate of soda, ammonium sulphate and potash nitrate upon water movement and to determine if sodium nitrate or potash nitrate fertilization could be modified so as to improve permeability in a heavy clay soil from Field 11, Ewa Plantation Company. A short history of this field may be of interest. Previous to 1920, difficulty had often been experienced in ripening cane on this field on account of a high water table. A system of tile drainage was installed at this time at a depth of four feet in order to lower this water table with a view toward ripening the cane. One result of this drainage system has been to remove large quantities of salt from the soil. On the other hand permeability has been quite variable and notably better cane growth has characterized the better drained spots. In fact, at the beginning of the last ratoon crop a number of poorly drained areas had to be replanted on account of the complete failure of the stubble to survive the environment produced by the poor drainage and salt accumulation. It may be seen, therefore, that this soil was excellently suited to the experiments which we had in mind. It might be mentioned that nitrate of potash was being used as the nitrogen carrier in this field because of the fact that it is deficient in potash.

Experimental

This study involved three series of experiments. The soil was ground to pass a 60-mesh sieve. Soil columns 16 cm. in length—approximately 100 grams of

soil—were prepared as carefully and uniformly as possible in small glass percolators. The soil columns thus prepared were placed under a head of 100 cc. of water for all tests. The rate of water movement was determined by noting the volume of percolate at intermittent periods of time. All solutions of nitrogen salts were made up to contain 5 grams per litre or 0.5 per cent salt.

Series 1: The purpose of the first series was to show the residual effects of the salts when dissolved in salt free water or water containing no other salines. Ten soil columns were used involving a duplicate for each salt, and checks which were leached with water alone. Four leachings of 100 cc. each were made on each column. Following this all columns were placed under an equal head of distilled (salt free) water and the residual effect of the salts on water movement determined.

A salt solution will, with rare exceptions, show a more rapid rate of water movement than pure water through a soil, which held true in this soil. All the salt solutions moved faster through the soil columns than water alone with nitrate of lime showing the highest rate. However, on changing all the columns to a head of pure water they all "froze up" with the exception of the one which had received nitrate of lime, and this continued to permit the water to pass just as rapidly as before. The residual effect is illustrated graphically in Fig. 1, in which rate of percolation is shown by plotting volume against time.

Series 2: It is a matter of common observation in the Islands that the coral fields are usually fields that "take water" well. The question arises as to the effect of supplementing nitrate of soda or other nitrogen salts with coral rock or gypsum. Series 2 was conducted to determine this.

The experimental procedure used was the same as that described in Series 1. Where calcium carbonate or sulphate (gypsum) were added they were placed on the surface of the soil column at the rate of 1 gram per 100 grams of soil, or one per cent the weight of the soil. This series included thirty soil columns or fifteen different treatments in duplicate. Ten columns were repetitions of Series 1; ten had additional applications of calcium carbonate; and ten had applications of gypsum. Distilled water solutions of the salts were used and the columns leached four times with 100 cc. at each leaching. The rate of flow was taken as in Series 1 and then all columns were placed under equal heads of pure water and the residual effect noted. The results are shown graphically in Fig. 3.

In all cases where nitrate of lime was used an excellent rate was maintained. The effect of carbonate and sulphate of lime upon pure water is also of interest. Under calcium carbonate and gypsum in Fig. 3 the solid lines represent the rate of movement for the first application of water following the salt solution, and the dotted lines the second leaching or after the salts had been leached out. In other words, the dotted lines represent the residual effect of the salts.

Series 3: The experiments described in Series 1 and 2 show the residual effects of the salts when dissolved in distilled water. But the residual effect is always notably influenced when other salts are present in the water. For this reason another series of soil columns was prepared and in place of distilled water

plantation pump water was used. Our island waters are often high calcium and magnesium waters which type will usually limit the fixation of other bases in the soil and therefore lessen their residual reaction. The plan of Series 3 was exactly as described in Series 2, except that the nitrogen salts were dissolved in pump water. The residual data from this series is shown graphically in Fig. 4.

It will be noted that the residual effects of the several nitrogen salts are notably different where applied to the soil with pump water. In spite of the fact that the nitrate was applied in amounts somewhat greater than a field application, there is sufficient calcium and magnesium in the pump water to greatly limit the fixation of sodium by the soil. The pump water used was the same as that used on this soil in the field and had the following composition:

Total solids	1258	ppm
Calcium Ca	82	"
Magnesium Mg	79	"
Sodium Na	113	"
Potassium K	6	"
Chlorine Cl	448	"
Sulphate SO_4	97	"

In this series none of the soil columns "froze up" within the time of the experiment, and, with the exception of sodium nitrate, in the presence of calcium carbonate all showed excellent to fair water movement.

Effect on Zeolites

As previously stated, the ability of a soil to take water is largely a function of the nature of the bases combined with the zeolite silicates of the clay fraction. Fortunately, there is a great difference in the affinity which the zeolites have for the various bases, and this affinity is least for sodium as compared to magnesium and calcium, which three are the dominant soluble bases in soils and water. Therefore, a considerable excess of sodium in the soil solution must be present for the fixation of this element to reach injurious proportions. In order to make the preceding experiments more complete the soils from the soil columns were analyzed to determine what the effect of the treatments had been upon the composition of the zeolites. These data are given in the following table and are shown graphically in Figs. 4 to 11:

Fig. 4. Fixation of ammonium from ammonium sulphate has been largely at the expense of the calcium and magnesium, both of which were materially reduced. However, there is nothing in the data to indicate that the soil has suffered any permanent injury, but rather that in an experiment such as this where the ammonium sulphate is not given time to nitrify, a small amount of ammonium zeolite has been formed which on hydrolysis caused a temporary dispersion of the clay.

Fig. 5. Fixation of calcium has taken place almost entirely at the expense of the magnesium. The sodium and potassium already only present in small amounts have not been materially affected.

TABLE SHOWING PER CENT ZEOLITE (REPLACEABLE) BASES IN SOILS FROM SERIES 2 AND 3 LEACHING EXPERIMENT

	Calcium Carbonate					Gypsum					Water				
	Am. Sul.	Cal. Nit.	Sod. Nit.	Pot. Nit.	Water	Am. Sul.	Cal. Nit.	Sod. Nit.	Pot. Nit.	Water	Am. Sul.	Cal. Nit.	Sod. Nit.	Pot. Nit.	Water
Calcium pump	.212	.339	.232	.205	.218	.225	.321	.257	.252	.284	.148	.298	.184	.164	.204
Calcium dist.	.179	.327	.138	.142	.227	.133	.330	.226	.117	.257	.107	.270	.091	.128	.183
Magnesium pump	.054	.062	.090	.072	.115	.047	.040	.063	.042	.074	.062	.050	.105	.081	.119
Magnesium dist.	.028	.018	.046	.034	.096	.020	.023	.049	.031	.069	.040	.020	.046	.060	.100
Potassium pump	.014	.020	.022	.244	.020	.012	.015	.017	.217	.015	.006	.017	.018	.267	.020
Potassium dist.	.012	.021	.030	.347	.023	.013	.024	.031	.328	.036	.015	.034	.021	.377	.027
Sodium pump	.023	.022	.070	.028	.023	.018	.018	.050	.023	.018	.025	.020	.104	.028	.021
Sodium dist.	.026	.023	.062	.034	.024	.017	.019	.048	.029	.021	.019	.011	.083	.027	.017
Ammonium pump	.143					.095					.161				
Ammonium dist.	.152					.164					.190				

Fig. 6. Fixation of sodium from sodium nitrate was largely at the expense of the calcium and magnesium.

Fig. 7. Fixation of potash also was largely brought about by a replacement of calcium and magnesium. The excessive fixation of potash is extremely significant and of more than passing interest. The data indicate that potash is fixed in forms other than as the zeolites, possibly physical absorption.

In Figs. 8, 9, 10 and 11 are shown graphically the advantages of pump water over pure water as a means of retarding fixation of sodium from sodium nitrate. The soils from the soil columns used in Experiments 2 and 3 show in nearly every case that those leached with pump water are higher in calcium and magnesium but lower in sodium and potassium.

Conclusions

These data strongly endorse the use of nitrate of lime as a nitrogen carrier for our heavy clay soils, at least until the mechanical condition of the soil has improved sufficiently to permit average permeability, and that nitrate of soda is the least desirable for such types. Even when applied with calcium carbonate or calcium sulphate, using pump water, drainage is much slower where nitrate of soda is used. In fact, the experiments show little or no advantage in supplementing nitrate of soda with limestone or gypsum. On the other hand, the effect of the limestone and gypsum alone on permeability would make for better drainage between nitrate applications, and therefore a gradual improvement in the mechanical condition of the soil.

The extremely hygroscopic property of nitrate of lime has been the cause of much prejudice against its use. It was for this reason that some knowledge of the effect of lime and gypsum upon the residual properties of nitrate of soda was studied. The conclusion appears inevitable that nitrate of lime is so far superior to the other forms of nitrogen for improving the permeability of heavy clay soils as to favor its extensive adoption on such soil types if improvement in permeability is desired.

On the basis of this same property of nitrate of lime there is probably need for caution against loss of nitrogen by too rapid permeability if it is desired to use this form of nitrogen on well drained soils.

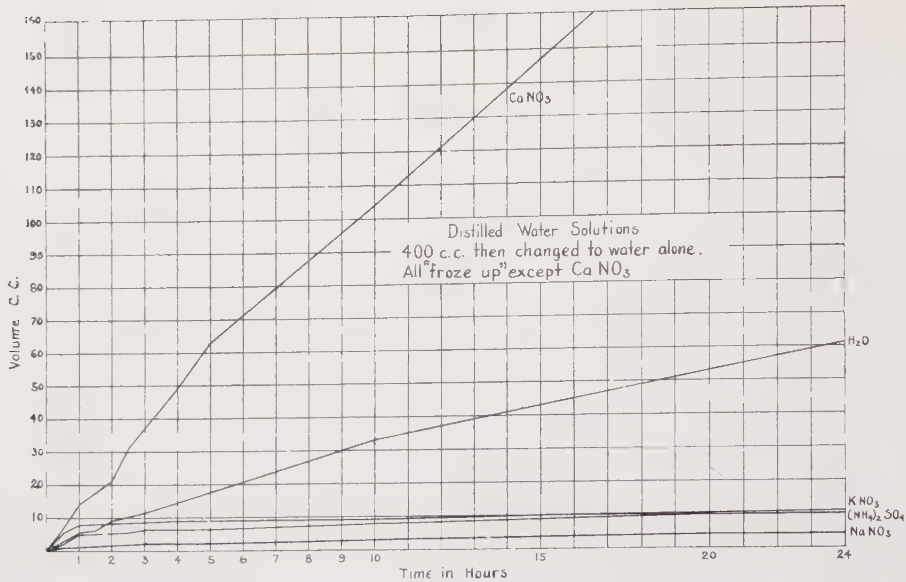


Fig. 1

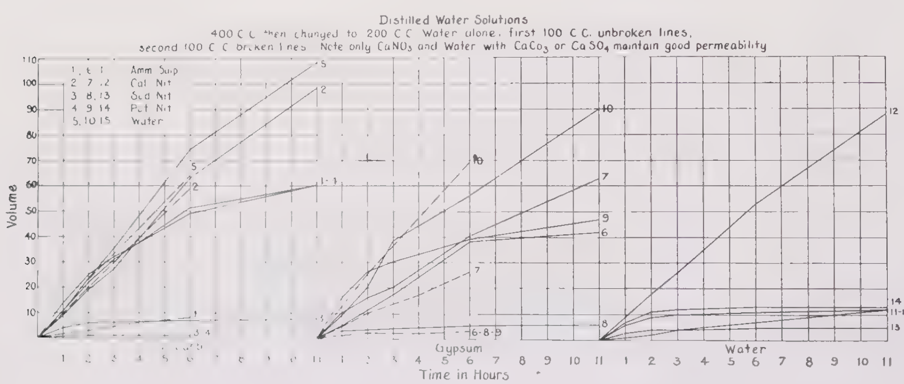


Fig. 2

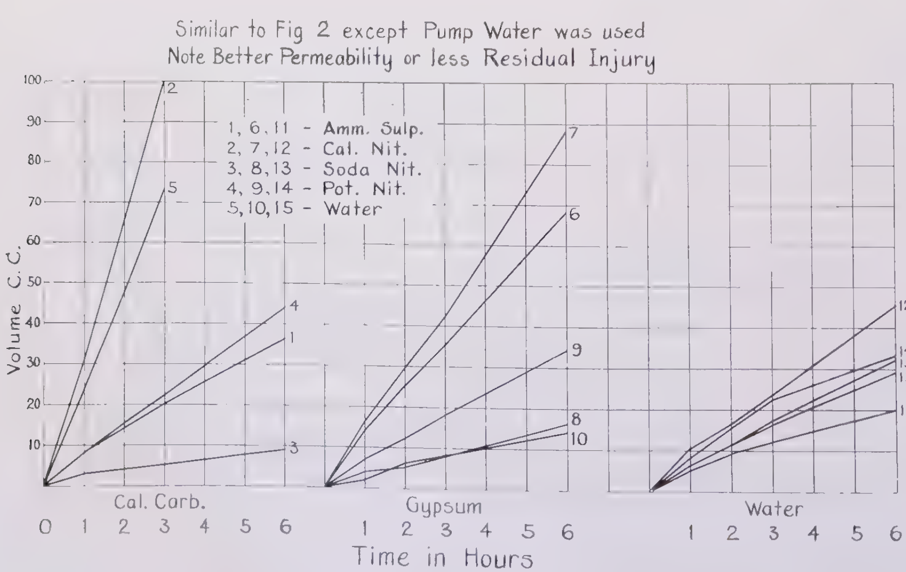


Fig. 3

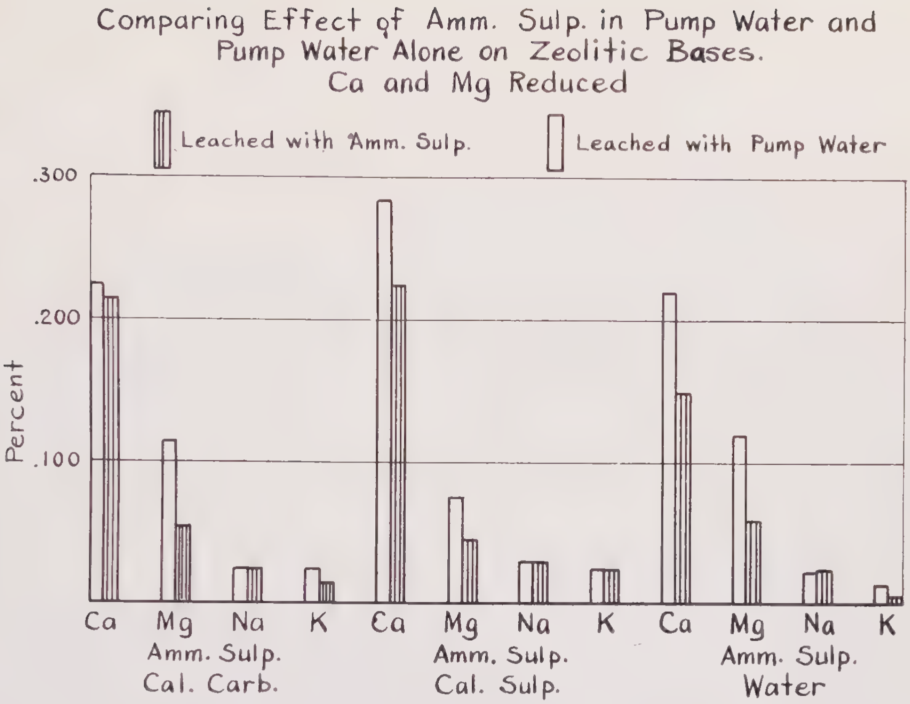

Comparing Effect of Amm. Sulp. in Pump Water and
Pump Water Alone on Zeolitic Bases.
Ca and Mg Reduced
Leached with Amm. Sulp.
Leached with Pump Water
.300
.200
.100
Percent
Ca Mg Na K
Amm. Sulp.
Cal. Carb.
Ca Mg Na K
Amm. Sulp.
Cal. Sulp.
Ca Mg Na K
Amm. Sulp.
Water

Fig. 4

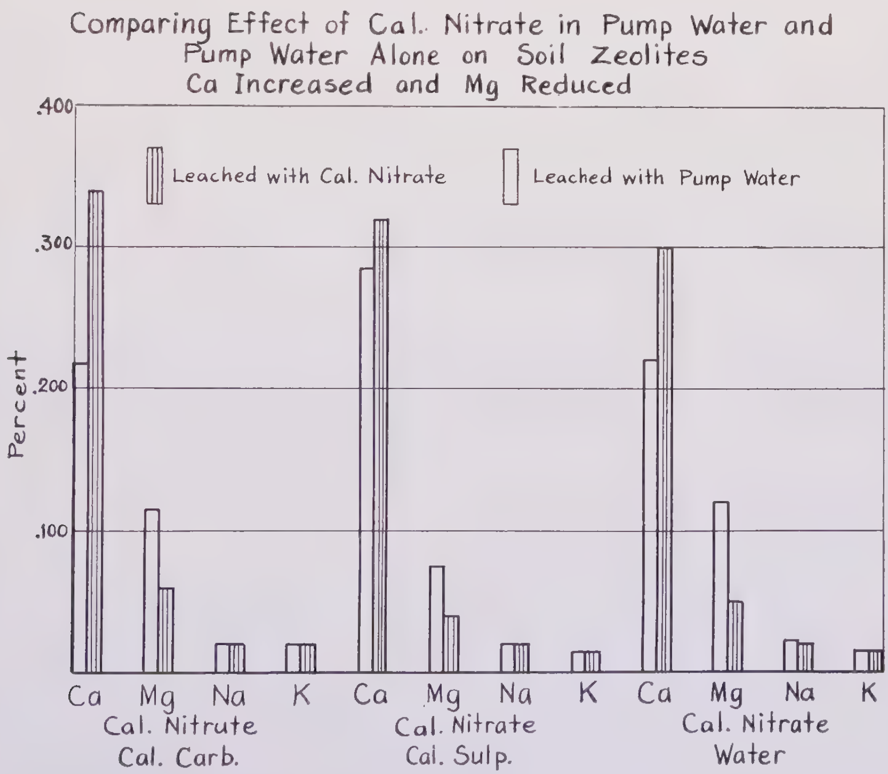

Comparing Effect of Cal. Nitrate in Pump Water and
Pump Water Alone on Soil Zeolites
Ca Increased and Mg Reduced
.400
Leached with Cal. Nitrate
Leached with Pump Water
.300
.200
.100
Percent
Ca Mg Na K
Cal. Nitrute
Cal. Carb.
Ca Mg Na K
Cal. Nitrate
Cal. Sulp.
Ca Mg Na K
Cal. Nitrate
Water

Fig. 5

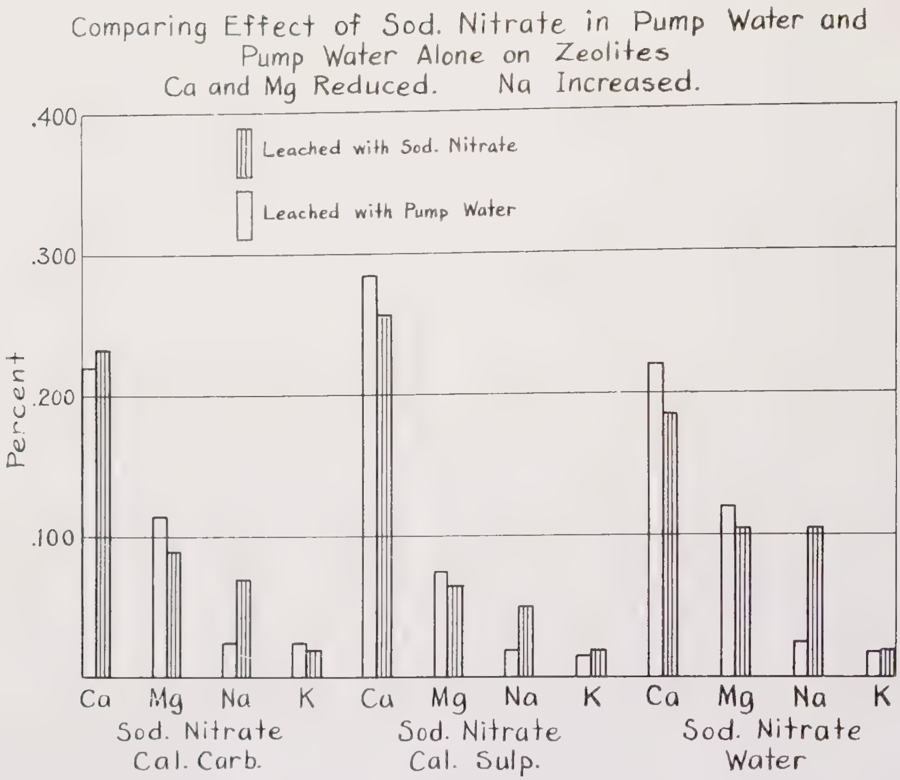

Comparing Effect of Sod. Nitrate in Pump Water and
Pump Water Alone on Zeolites
Ca and Mg Reduced. Na Increased.
Leached with Sod. Nitrate
Leached with Pump Water
Percent
.400
.300
.200
.100
Ca Mg Na K
Sod. Nitrate
Cal. Carb.
Ca Mg Na K
Sod. Nitrate
Cal. Sulp.
Ca Mg Na K
Sod. Nitrate
Water

Fig. 6

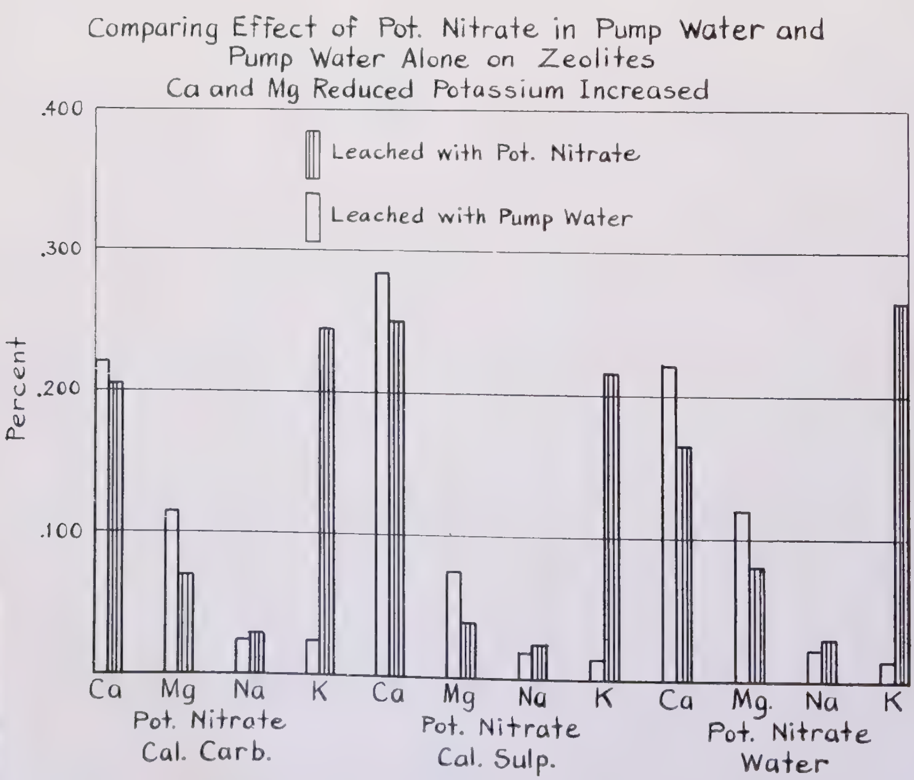

Comparing Effect of Pot. Nitrate in Pump Water and
Pump Water Alone on Zeolites
Ca and Mg Reduced Potassium Increased
Leached with Pot. Nitrate
Leached with Pump Water
Percent
.400
.300
.200
.100
Ca Mg Na K
Pot. Nitrate
Cal. Carb.
Ca Mg Na K
Pot. Nitrate
Cal. Sulp.
Ca Mg. Na K
Pot. Nitrate
Water

Fig. 7

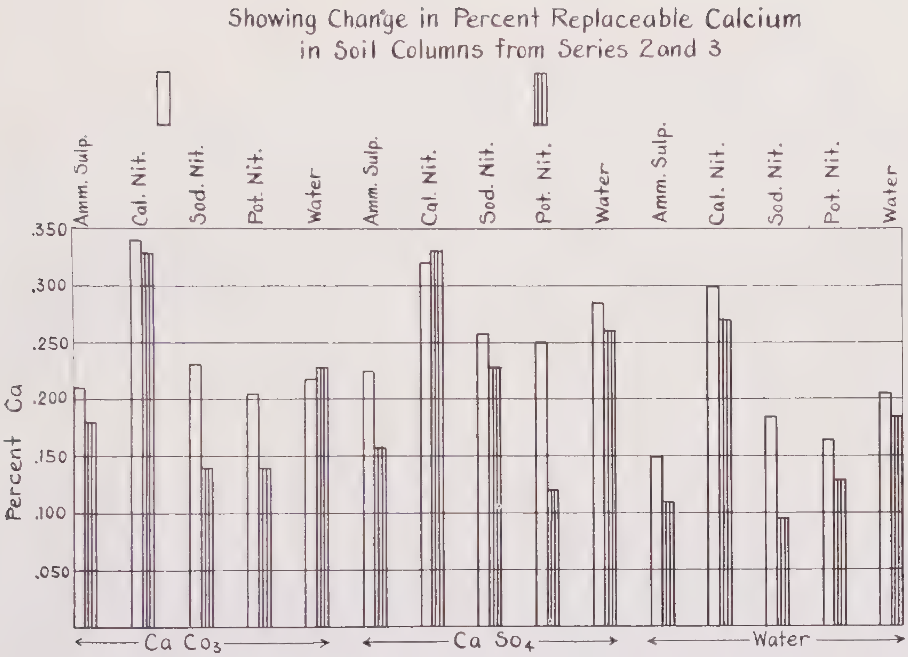

Showing Change in Percent Replaceable Calcium
in Soil Columns from Series 2 and 3
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
.350
.300
.250
.200
.150
.100
.050
Percent Ca
Ca Co3
Ca So4
Water

Fig. 8

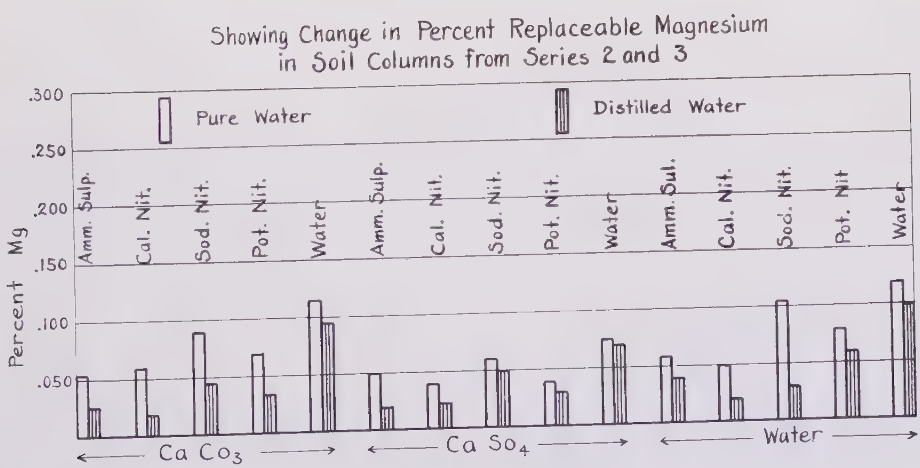
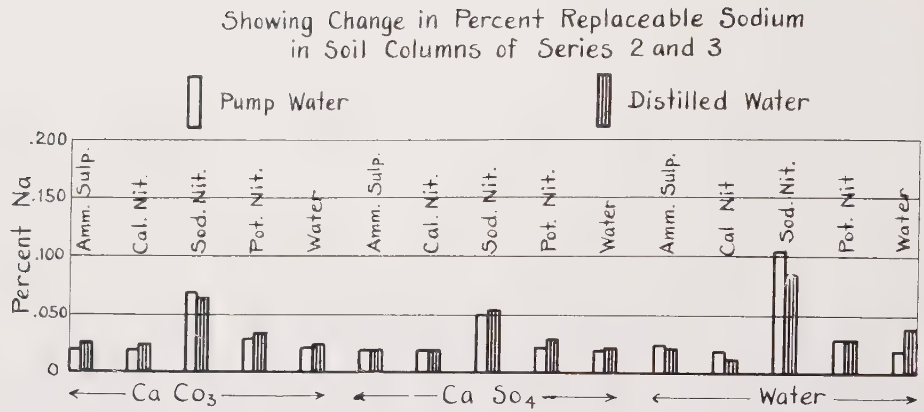
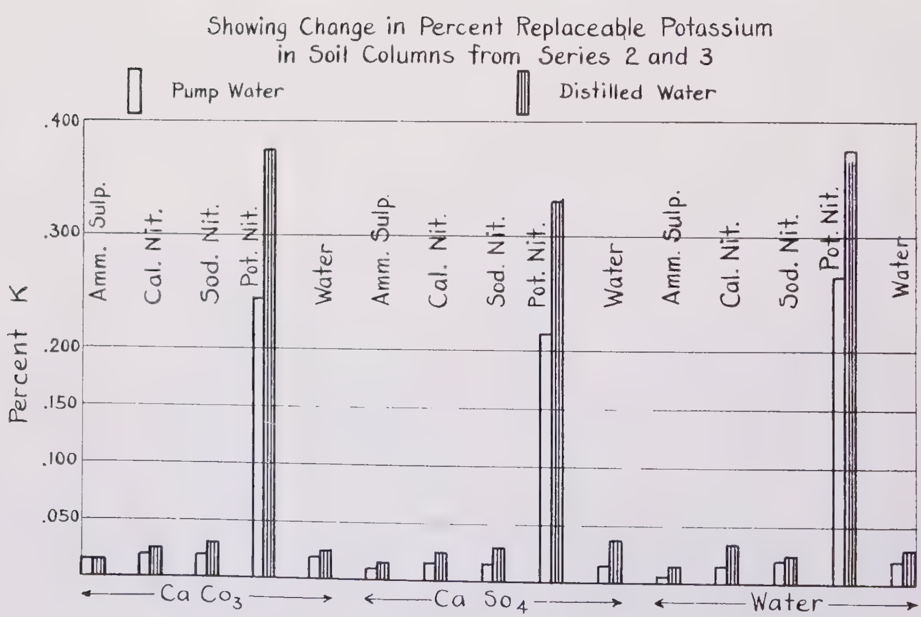

Showing Change in Percent Replaceable Magnesium
in Soil Columns from Series 2 and 3
Pure Water
Distilled Water
.300
.250
.200
.150
.100
.050
Percent Mg
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sul.
Cal. Nit.
Sod. Nit.
Pot. Nit
Water
Ca Co3
Ca So4
Water

Fig. 9



Showing Change in Percent Replaceable Sodium
in Soil Columns of Series 2 and 3
Pump Water
Distilled Water
Percent Na
.200
.150
.100
.050
0
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal Nit
Sod. Nit.
Pot. Nit
Water
Ca Co3
Ca So4
Water

Fig. 10



Showing Change in Percent Replaceable Potassium
in Soil Columns from Series 2 and 3
Pump Water
Distilled Water
Percent K
.400
.300
.200
.150
.100
.050
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Amm. Sulp.
Cal. Nit.
Sod. Nit.
Pot. Nit.
Water
Ca Co3
Ca So4
Water

Fig. 11

Notes on Irrigation Investigations and Control at Ewa Plantation Company

By H. R. Shaw

Plantation Irrigation Equipment

Supply: The Ewa Plantation Company is dependent on its artesian supply for irrigation. Rainfall in the Ewa district is extremely light, as is shown in the following table:

COMPARISON OF ANNUAL RAINFALL—EWA PLANTATION COMPANY

Year	Mill	Apokaa	9B Reservoir	Waimanalo	No. 6 Reservoir
1924	21.12	19.45	19.84	16.84	20.52
1925	10.04	10.01	10.18	6.34	10.58
1926	12.61	13.53	11.61	13.97	13.40
1927	41.25	47.53	50.82	43.22	46.63

The exceptionally high rainfall during the month of December, 1927, accounted for nearly half of the total rainfall for the year.

Pumps: The plantation has ten irrigation pumps in use. Nine of these are electrically driven, and the tenth is driven by steam. The maximum pumping capacity of the whole is 105 M. G. daily, but the average for the year is about half of this figure.

Field Layout: The so-called "Renton System" of irrigation has been adopted as the standard plantation practice. On the plant fields the watercourses are 70 feet wide, the length varying with the contour. The field is irrigated one line at a time until the cane is three or four months old and has closed in. The watercourse is then cut in the center, making two watercourses 35 feet wide instead of one watercourse 70 feet wide. Alternate lines are then cut to form a "U," and every two lines are irrigated as a unit. This system not only shows an advantage in increased acreage covered by the irrigator, but also gives an increased yield of sugar by the utilization of land formerly occupied by the additional watercourse.

Survey: All field surveys are of gross acreage, and are taken from a point two and a half feet out from the actual cane boundary. The survey includes all ditches in the area, but excludes roads. Watercourse areas are from center of watercourse to center of watercourse, and from center of level ditch to center of level ditch.

Ditch Lining: Although the plantation ditches, especially those on makai, coral soils, show a high seepage rate, there is little ditch lining being put in by the plantation. This is due to the fact that the plantation lease expires in a few years, and the management is avoiding permanent improvements of this nature.

Water Measurements

Equipment: The plantation has in use five standard rectangular weirs, five Steven and three Gurley water stage recorders, and about one hundred Lyman meters.

Installation: The Lyman meter installations now in use on the plantation have a depressed "V" basin, and have the meter box placed on the side of the ditch. The installation is at such a depth below the level of the ditch that the proportion between the orifice and the wetted area of the gate will be as 1 to 3. For instance, if a one-square-foot orifice is used, the total wetted area of the gate should be four square feet. This insures submergence of the orifice at all times.

The plantation formerly advocated a meter installation with the meter above the orifice and placed in the center of the gate, but the installation described above has been found to be preferable and is taking the place of the gate installation. All installations are of redwood at a cost of approximately $6.00 each. Because of the short duration of the plantation lease, it has been inadvisable to install concrete structures, although it is realized that this form is more economical for permanent installations.

Lyman Meters: Ewa is strongly in favor of the Lyman meter. Although its limitations are realized, it is felt to be the most practicable and economical device for measuring water under field conditions. J. B. Menardi, Jr., in charge of water measurements, says: "With close adjustment and care, in installations meeting the requirements of the meter, the Lyman will check within 3 per cent." Ewa also finds the Lyman meter valuable as a "policeman," in seeing that each of several fields on the same main ditch gets its share of water, and that no night water is being stolen.

The Lyman meters are checked against a "V" notch weir at the start of the irrigating season, and thereafter as necessary. It has been found that most inaccuracies of the Lyman meter occur at low heads: hence, the meter is checked against a small stream over the "V" notch weir rather than against greater heads. An installation for checking against a larger rectangular weir is also provided. A standard meter, which is kept at 100 per cent efficiency by frequent checking is substituted in the field installations during the course of the season to detect any inaccuracies in the field meters.

Irrigation Control

The entire plantation is under an extensive system of irrigation control. This control is based on the interval between irrigations rather than on the amount of water applied at each irrigation. It was found that the term "acre inches per acre" and "gallons per man" meant little to the average ditchman or irrigation overseer; while "number of days between irrigations" and "number of days per round" were readily applicable.

Type Fields: About 2,500 of the plantation's 8,000 acres are under actual meter measurement. Typical fields under the classification of "General," "Wet,"

"Coral" and "Pali" conditions have been chosen, and a series of interval tests installed in each of these type fields.

Interval Tests: In these interval tests, four treatments are given:

1. Maximum: in which an excessive amount of water is applied by irrigating at more frequent intervals.

2. Minimum: in which water is applied in the least amount possible for growth.

3. Normal; an optimum application, based on what the plantation treatment would be under ideal conditions as to water and labor.

4. Check: the application given by the plantation to the surrounding fields.

The intervals vary from 15 to 30 days, depending upon the soil type, the age of the cane, and the time of year. (For a more complete report on interval tests at Ewa, see "An Investigation to Determine the Relation of Water to Maximum Sugar Yield," Renton and Alexander, 1926.)

Growth Measurements: Correlated with the interval tests, growth measurements are made in each plot in order to determine at what interval optimum growth occurs. A minimum of twenty-five stalks is measured in each level ditch plot. From these data the optimum interval of irrigation of each soil type and for various ages of cane is determined, and a definite schedule of irrigation made. The data are interpreted liberally, and the irrigation schedule readjusted as further investigation may indicate.

Irrigation Schedule: The general irrigation schedule is as follows:

Irrigation No.	*Time*
1	Day planted.
2	Four days later.
3	Seven days later.
4, 5, 6	Ten days later.
7, 8	Ten to fifteen days later, depending on weather conditions.

From this time the irrigations are controlled by the irrigation schedule, depending on the month planted and the soil type.

Water Economy: From data gathered in these investigations, the problem of water application during the summer months when there is a scarcity of water has been solved for Ewa conditions. The young cane is forced by giving more frequent applications, and the more mature cane allowed to go with longer intervals. For instance, the irrigation schedule for the month of July, when there is a shortage of water, would be:

3 to 8 months cane........	15 to 20 days interval
8 to 12 months cane........	20 to 25 days interval
12 to 15 months cane........	25 to 30 days interval

Ripening Schedule: By correlating pre-harvest juice samples, growth, soil moisture and other related factors, an irrigation schedule for type fields during the three or four months directly preceding their harvest has been evolved. This includes the period during which irrigation is gradually retarded, in order to ripen the juice, and the period at which irrigation should completely cease.

Irrigation Reports

Staff: In addition to the men required for growth measurements, juice samples, etc., one member of the staff of the department of agricultural research and control, and two clerks (one man for control and one man for research) are used on the irrigation work alone. However, the ditchmen have been trained to adjust the orifice gates and take the meter readings, thus eliminating an otherwise expensive item in irrigation control.

Reports: The main irrigation reports used at Ewa are:

1. Irrigation Meter Record (Form I).
   Filled by overseer from readings supplied by the ditchman in charge of the field, and submitted after each day's irrigation.
2. Ditch Irrigations (Form II).
   Filled by the section overseer, and showing the number of ditches irrigated in his section daily.
3. Field Areas Irrigated (Form III).
   Showing percentage of field area irrigated daily, accumulated on the round to date, and the equivalent to this percentage in days performance as scheduled. Used as a basis for the Irrigation Control Board, to be described later.
4. Irrigation Daily Record Sheet (Form IV).
   Summary of labor, water, and round data for each field.
5. Growth Measurement Sheet (Form V).
   Detail and summary of growth measurements to each experimental field.
6. Irrigation Data (Form VI).
   A memorandum to section overseers, showing the actual result in water and labor used in each field as compared with the scheduled application as determined experimentally. A valuable report, in that it keeps the interest of the section lunas aroused, and shows them clearly the efficiency of their work.
7. Irrigation Record, Index Card (Form VII.)
   A convenient summary of irrigation results for each field. Kept in an index file for ready reference.
8. Growth Measurement, Index Card (Form VIII).
   A summary of cane growth, filed with the irrigation record.

FORM I

EWA PLANTATION COMPANY

Irrigation Meter Records

Field No. ________________ Ditch No. ________________

Date ________________ Meter No. ________________

ORIFICE FACTOR	READING
Start	
Finish	
Start	
Finish	
Start	
Finish	
Total Acre Feet	
Men Irrigating	
Man Hours Irrigating	
Deductions	

NAME ________________

ROUND ________________

FORM II

DITCH IRRIGATIONS

Section No. 9 Antone Freitas.

FIELD	DITCHES PAU
"A" (8.04 Ac.)	
"A" (38.30 Ac.)	
"A" (and AS No. 4) (48.61)	
"A" (78.58 Ac.)	
"A" (110.47 Ac.)	
"B"	
"D" and A.S. No. 4	
"E"	
23-A Gulch	
AS No. 1 (33.55 Ac.)	
AS No. 1 (35.50 Ac.)	
AS No. 2 (36.15 Ac.)	
AS No. 2 (44.32 Ac.)	
Rounds Pau	
Date	
By	

FORM III

SCHEDULED INTERVAL	DAYS		MONTH OF AREA IRRIGATED		
DATE	IRRIGATED	DITCHES	% Daily	% Accumulated	In Days
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
Total					

1. Total acres of Experiments irrigated ....
2. Total acres of Dry Spotting ....
3. Total acres irrigated—excluding 1 and 2 ....

Grand total acres irrigated during month ....

Field........................ Experiment Area........................

Crop........................ Field Area........................ Total Area........................

FORM IV

FIELD OR LOCATION.................................AREA.................................MONTH OF.................................192........

Date	MEN		ACRE FEET		Acre feet per man	Gallons per man applied	ROUND DATA			
							MEN		ACRE FEET	
	I DS	Total	I DS	Total			I DS	Total	I DS	Total
Forward										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										

MONTHLY SUMMARY

Average acre feet per acre.................................. Avg. gallons per man per day..................................

Average acre inches per acre.................................. Avg. per man per day..................................

Rainfall.................................. Compiled by..................................

Total acre inches per acre.................................. Checked by..................................

FORM V

GROWTH MEASUREMENT SHEETS

FIELD ... EXPERIMENT... DITCH... DATE... 192...

Line	No.	Base to Top	Circumference	Line	No.	Base to Top	Circumference	Line	No.	Base to Top	Circumference
WC #	1			WC #	1			WC #	1		
	2				2				2		
	3				3				3		
	4				4				4		
	5				5				5		
	Avg.				Avg.				Avg.		
WC #	1			WC #	1			WC #	1		
	2				2				2		
	3				3				3		
	4				4				4		
	5				5				5		
	Avg.				Avg.				Avg.		

GENERAL SUMMARY

	Days	WC#	WC#	WC#	WC#	WC#	Mean Growth	Average Circumference
Base to Top								
Previous Base to Top								Cubic Inches
NET GROWTH								

Measured by... Entered by... Compiled by... Checked by...

FORM VI

IRRIGATION DATA

(Acre Basis)

Field ... Ditch...

Date ...

	Average Practice	Actual
WATER		
Gals. per Man Day	...	...
Acre inches	...	...
LABOR		
Acres per Man Day	...	...
Interval	...	...

REMARKS

...

...

Report compiled — By whom...

Date...

FORM VII

ACME 7851-8 IRRIGATION RECORD ________

AREA ________

ROUND NO	DATE APP'L		INTER VAL DAYS	WATER APPLIED				LABOR		Rate of Flow	Monthly-Inches		
				ACRE-FEET		ACRE-INCHES							
	MONTH	DAY		TOTAL	PER ACRE	PER ACRE FOR RD	DAILY BASIS	MEN ~~HOURS~~ TOTAL	ACRES PER MAN PER 10 HRS	Gals.per man per 10 hrs.	Water	Rain	Total

FIELD DITCH TREAT

FORM VIII

ACME 7852-8

NO. OF STALKS AVERAGED ________

EWA PLANTATION COMPANY

RECORD OF GROWTH MEASUREMENT AND CANE TONNAGE

DATE		INTER-VAL	ELONGATION OF STALK					CIRCUM-FERENCE INCHES	GROWTH CU. FT.	MONTHLY GROWTH % OF TOTAL	CANE PER ACRE PER MONTH TONS
					PRO-RATING						
MONTH	DAY		DURING PERIOD INCHES	DAILY INCHES	DAYS	RATE	MONTHLY INCHES				

FIELD DITCH TREAT

Irrigation Control Board

Purpose: Ewa Plantation Company has inaugurated a system of plantation control which has proved most effective in increasing the efficiency of irrigation, showing graphically to the plantation management the irrigation status and efficiency of each field, and in keeping the section overseers actively interested and alert in bettering irrigation conditions in their fields. The control board has been in use for over a year, and has proved highly successful.

EWA SYSTEM OF IRRIGATION CONTROL

Section								IRRIGATION SCHEDULE — Days of Present Round																													
Field No.	Acreage	Crop	Irrigation Round Interval-Days 3	2	1	Last Round Completed	Ac. per Man Day Last Rd.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
23 D	40.8	1929	x 14	34	18	Feb. 17	1.10																	W		R			Y								
24 B	18.7	1929	32	14	18	Feb 29	1.33							R		W									Y												
20 A	64.5	1929	x 21	x 14	46	Feb 11.	-																									RW					Y
B	175.3	1929	33	x 14	48	Feb 13	0.88																				W		Y	G							

Yellow Peg at "Optimum Interval"

Red Peg at "Number of Days since Round Started"

Green Peg at "Number of Days since Round Started" When Time elapsed exceeds optimum interval.

White Peg at actual interval Corresponding to "Area percentage Covered."

Field 23 D: Desirable interval is 22 days.
Red peg shows 19 days already in field.
White peg shows 17 days scheduled Work completed.
Irrigators 2 days behind schedule.
"X" designates previous round interrupted by rain.

Field 24 B: Desirable interval 18 days.
Red peg shows 7 days already in field.
White peg shows 9 days scheduled Work completed.
Irrigators 2 days ahead of schedule.

Field 20 A: Desirable interval 30 days. Half red and half white peg shows irrigating gang on schedule.

Field B: Desirable interval 22 days.
White peg shows 20 days scheduled Work completed.
Green peg shows 23 days already in field, and that irrigating gang has exceeded desirable interval.

Optimum Interral Days

Percent of area irrigated to date

Actual Interval Days	1	2	3	4	5	6	7	8	9	10	11
1	100.0	50.0	33.3	25.0	20.0	16.7	14.3	12.5	11.1	10.0	9.1
2		100.0	67.7	50.0	40.0	33.3	28.6	25.0	22.2	20.0	18.2
3			100.0	75.0	60.0	50.0	42.9	37.5	33.3	30.0	27.2
4				100.0	80.0	66.7	57.2	50.0	44.4	40.0	36.4
5					100.0	83.3	71.5	62.5	55.5	50.0	45.4
6						100.0	85.7	75.0	66.7	60.0	54.5
7							100.0	87.5	77.9	70.0	63.7
8								100.0	89.0	80.0	72.8
9									100.0	90.0	81.9
10										100.0	90.9
11											100.0

This Sheet gives "Actual Interval" relative to "Optimum" When "Percent of area to date" (See Form III) is known.

A White peg is placed in hole corresponding to this "Actual Interval."

Example: A field having an optimum interval of 11 days has been irrigated for 7 days during the present round. In this time the irrigating gang has completed 72.8% of the total field area Under "11" in the optimum interval column, we find 72.8% equivalent to 8 days actual interval (by following the horizontal column to the left.) Hence, the yellow peg would be under "11" on the board; the red peg at "7" and the white peg at "8"

H.R.S.
Mar 1928.

The accompanying illustration shows the general principles involved in handling the board.

The optimum interval for each field is taken from the irrigation schedule, and is based on experimental results in the soil section to which the field belongs. A yellow peg is placed under the day on which the irrigation should be completed.

The red peg represents the actual days of irrigation. It is advanced one space for each day of irrigation in the field.

The white peg represents the actual amount of work that is being done as compared to the scheduled time. If, for instance, an optimum ten-day interval had been fixed, the irrigators should cover 10 per cent of the total field area per day. If they should do 40 per cent of the field on the first day, they will have done four days scheduled work and are three days ahead of schedule. Thus, in this case, the white peg would be placed four spaces from the right of the board. The percentage of the field covered is taken from "Field Area Irrigated" (Form III).

If the irrigators are exactly on schedule, a red-and-white peg is used, as this represents the "number of days since round started," coinciding with "number of days scheduled." If the actual number of days in the field exceeds the optimum interval, a green peg is substituted for the red one to show that that field is operating below efficiency.

By such a system, the section lunas and the head overseer can more easily place men for each day's work, as they can readily see if a field is ahead or behind schedule, and can move irrigators to or from a field in order to maintain a proper balance of labor.

Additional Experiments

Policy: The present policy of the Ewa Plantation Company is to continue the experiments now in progress without adding extensively to their system of meter measurement. This is partially due to the fact that the short duration of their lease would not make it economical to expand in this line, and partially because the management feels that their present system should be perfected before additional work is done. W. P. Alexander, agriculturist, says: "Any system of water measurement should be based on experimentation. We feel that to merely measure the water going to the field, or to create a water balance between water pumped and water consumed in the field is of little value. We prefer to get exact data on smaller areas, representative of the whole plantation, and to apply data thus gained to the plantation in general, rather than to attempt to cover every field by irrigation measurement."

New irrigation experiments to be made will be for the purpose of correcting present errors in the plantation cultivation system. Experiments in ratooning are now under way, the problem being to determine whether it is better practice in saving water and in general economy to do a thorough and expensive job of ratooning at $6.00 or $8.00 per acre, or whether to do a less expensive piece of work at about $2.00 per acre. In other words, "just how thorough ratooning is necessary for economical sugar production?"

Another problem to be solved is: "During a period of water shortage, should cane on loam soils, or coral soils, be forced?" The plantation has already found it better economy to push the young cane during the summer, but whether better yields can be made by applying this water to loam fields where the water retention capacity is relatively high, or to coral fields that demand a great deal of water, is yet to be decided.

Addenda

Since the foregoing report was written, the plantation management has introduced an added improvement in its system of irrigation control as applied to the individual fields.

Under the previous system, water applications to the field were based on the interval since the last irrigation and on the number of days in which the current round should be completed. In this way it was possible for the period from start of round to finish of round to be completed in the scheduled number of days; but there was no assurance that each ditch within the field would be irrigated at the proper interval in relation to that particular point in the last irrigation. A few irrigators might start the round to a certain field and be able to cover only a small percentage of the area, due to lack of water. On the next day more water might be available, and the irrigators could work more rapidly and complete a greater area. If the irrigation control board showed the irrigators falling behind schedule, the section overseer would put more irrigators in the field in an attempt to finish the irrigation quickly and on the time schedule set for the entire field. Hence, by this variation in daily area covered, depending on the number and speed of the irrigators and on the water available, the entire field, from starting point to finishing point, might be completed in the scheduled interval of, say, 20 days, but there would be a variation in interval of from 14 to 28 days in the irrigation of specific ditches within the field.

To remedy this condition, an interval schedule for each ditch in the field has been set. The section overseer now knows exactly the number of ditches he should irrigate each day, as well as the number of men and the amount of water he will require. This system of application is valuable not only in keeping each part of the field on schedule, thus assuring the best growing conditions, but also in making it possible to give additional dry spot irrigations to ditches which have been found to demand more water than other parts of the field.

Reports from the section overseers have now been standardized and simplified by including all routine reports in one loose-leaf notebook. This report book consists of four parts:

1. *Time Book:* The daily time sheet for all fields on the section is kept in the front of the book. The loose-leaf sheets can be easily removed, left with the timekeeper for entering, and returned to the section luna for filing.

2. *Irrigation Report:* The scheduled date for irrigation of each ditch in the field is set a month in advance by the Department of Irrigation Control. The section overseer, by referring to the schedule in his notebook, attempts to keep his irrigations on schedule and marks the date on which the application was completed

He records the number of men irrigating daily in each ditch, the date on which the ditch irrigation was completed, and sets the date for the next irrigation of the ditch.

3. *Ripening Schedule:* Fields in the ripening zone which do not come under the regular irrigation rounds have a special schedule designed to gradually ripen off the field. By the use of this record, an exact history of each ditch will be maintained, while, previously, data were available only on the entire field.

4. Maps and blue prints of the fields in the section as well as special data and reports are kept in the back of the book.

The Introduction of Anaphoidea Calendrae Gahan Into Hawaii as a Possible Egg-Parasite of Our Sugar Cane Beetle Borer, Rhabdocnemis Obscura (Boisd.)

By Francis X. Williams

As a result of correspondence between Mr. C. E. Pemberton, Associate Entomologist of this Station, and Mr. A. F. Satterthwait, in charge of the United States Entomological Laboratory at Webster Groves, Missouri, I was detailed to proceed to Webster Groves for the purpose of accumulating and bringing back a quantity of living material of the tiny *Anaphoidea* wasp, known to be parasitic on the eggs of billbugs (*Calendra* spp.), that it might be liberated in Hawaii as a possible egg-parasite of our sugar cane beetle borer (*Rhabdocnemis obscura*). I arrived at Webster Groves on May 10 and completed my work there on July 21; reached Honolulu on July 31, and Paauhau, Hawaii, where most of the parasites were liberated, on August 1, 1928.

But for the aid given me by Mr. Satterthwait, this work could scarcely have been accomplished in one season. In anticipation of my arrival at Webster Groves, he had arranged for the collection of thousands of living billbugs—as egg producers—turned over for my use a considerable part of the laboratory, gave me the help of others of his staff, and freely of his own time and experience; and in addition, there was his excellent entomological library ready at hand.

Billbugs are a group of weevils, and are so named because of the beak or "bill" which forms so prominent a portion of their features. One of the species is known as the "curlew-bug," and anyone who is acquainted with both bird and beetle can readily detect a resemblance between the two. These snout beetles range in size, according to species, from considerably smaller to much larger than our sugar cane beetle borer, and so, too, do the eggs vary. There is usually but one brood a year. As a rule billbugs pass the winter in the adult stage. They lay eggs in

spring and summer; these hatch in from four to fifteen days; the resulting grubs feed for a few weeks to well over two months, when they transform to pupae that in a week or so produce the adults that are destined to hibernate. Some of these insects are well known to the farmer, for they are destructive to cereal and forage crops, not only as larvae, but frequently, too, as adults. We have but to mention here such pests as the timothy billbug (*Calendra zeae*), the maize billbug (*C. maidis*), and the blue-grass billbug (*C. parvulus*).

Billbugs in general bear a good deal of natural resemblance to our sugar cane beetle borer. Indeed, in bygone days, when classification was not so discriminating, both groups were placed under the genus *Sphenophorus,* but later they were separated out as *Calendra* and *Rhabdocnemis.* Like the sugar cane beetle borer, many billbugs bite a small hole or cell into the plant tissue, turn about and deposit an egg therein, and the short, paunchy grubs of each genus are very much alike, and so, too, the pupae.

It was years ago, while working on the biology of his favorite group, the billbugs, that Mr. Satterthwait made the discovery that some of their eggs were parasitized by a tiny blackish wasp less than a millimeter in length. The insect was later described as *Anaphoidea calendrae.* Its wings are fringed with long hairs, and it belongs to the wasp family Mymaridae, which includes our *Paranagrus,* leafhopper egg parasites. Mr. Satterthwait succeeded in rearing many generations of *Anaphoidea* and found that their complete life-cycle involved from fourteen to about seventeen days, depending largely upon temperature. Also, that these wasps did not breed successfully in any but comparatively fresh *Calendra* eggs. He found, however, that they readily accepted for oviposition therein the eggs of some half dozen or more species of these billbugs. Such eggs, though they varied greatly in size, must all have had some sort of *Calendra* odor, taste or texture acceptable to the parasite. Furthermore, from a few to many individual wasps issued from each parasitized *Calendra* egg, said number being determined in part by the size of the egg host and (or) by the degree of its parasitism, the writer having obtained seven females and one male *Anaphoidea* from a single egg of *Calendra maidis* on one occasion, and on another, eighteen females and three male wasps from an egg of the same species. While eggs of the smallest billbug at Webster Groves may sometimes disclose but two or three parasites, the yield in nature is normally six or seven adult wasps per such an egg. The size of the individual wasp is also correlated with that of the billbug egg. The female wasp is almost invariably produced in far greater numbers than the male.

Mr. Satterthwait has a great deal of data on this *Anaphoidea* parasite, which it is hoped will soon be published.

The fact that *Anaphoidea* successfully parasitizes the eggs of many species of billbugs, cousins to *Rhabdocnemis,* fully justifies, we believe, the attempt made to establish it on the beetle borer in Hawaii.

Billbugs collected before my arrival in Webster Groves, and also subsequent thereto, were placed in metal salve boxes, usually partly filled with soil, and provided with grains of corn as food, and put in a refrigerator to retard their activities

until *Anaphoidea* wasps could be obtained from the field. Billbugs are very hardy and stand refrigeration—even out of season—quite well.

Since the *Anaphoidea* wasp passes the winter in the eggs of its host, a quantity of last year's (1927) grass stems, particularly of timothy (*Phleum pratense*) was brought into the laboratory and placed in tight boxes in which two holes had been drilled for the insertion of testtubes to draw to light the insects that emerged in these boxes. In this wise, timothy stems boxed on May 19, yielded on May 23 and 24, two male and three female *Anaphoidea* wasps, probably derived from a single parasitized *Calendra* egg. These wasps, however, failed to parasitize the billbug eggs offered them. Since it was now obvious that *Anaphoidea* had already emerged from winter quarters, and that for some time billbugs had been laying eggs in the field, a search for parasitized billbug eggs laid in green grass stems, at or near their base, was undertaken, with the result that on June 5, thirteen eggs of *Calendra minima,* a small species of billbug, were found in Red top grass (*Agrostis alba*), and one of these eggs showed by its mixed slaty black and whitish color that it was parasitized by *Anaphoidea* in an advanced stage of development, the individual wasps themselves being more or less discernible therein. Very soon thereafter, other parasitized *minima* eggs were found by Mr. Bucholtz, assistant to Mr. Satterthwait and by myself. It was from seven parasitized *minima* eggs, termed generation A for convenience, that the *Anaphoidea* stock, generation D, was derived, and that was liberated two months later in the cane fields of Hawaii.

Billbugs were taken out of cold storage as needed and fed in part with timothy bulbs, and in part with pieces of green corn stems obtained from the southern states, at first in small quantity, but later on in ample amounts. The green corn stems proved best, both as billbug feed and as a medium for egg laying, for they could be easily split up and examined. This daily work of feeding the billbugs, of cutting their eggs out of the plant tissue, and of exposing them for parasitization, soon assumed large proportions, so a young assistant, Mr. Ralph Swain, was engaged to take over most of this routine work, which he did very creditably.

The *Calendra* eggs were usually placed along the trough of a split grass stem serving as a carrier and so exposed in slender testtubes to *Anaphoidea.* As the work went on and more billbug eggs and wasps became available, larger tubes were often used and the eggs arranged on a piece of corn rind. The *Anaphoidea,* in number from a half dozen or so to perhaps fifty or more, were kept in these egg-charged tubes from a few hours to a day or more. As a rule, some of the wasps immediately became interested in the eggs, tapped them with their feelers, and pierced certain of them with their rather long ovipositor. Rarely, however, did I obtain more than 50 per cent parasitism, usually much less. This state of affairs was probably in part due to some fault in the technique, and to the fact that some of the billbug eggs had lost their attraction through age. The wasps, too, are not so easy to handle as many other small parasites, and in captivity live only four or five days; less in very warm weather. Following Mr. Satterthwait's method, these exposed billbug eggs were placed each in a little depression in the clean soil in a metal salve box, and the lid put on; thus about the right degree of moisture was secured for them and they kept very well. Two or three days after being exposed

to *Anaphoidea,* white blotches or areas appeared in certain eggs, showing that these had been parasitized. Some days later the eyes of the *Anaphoidea* pupae could be seen through the egg shell, and finally the slaty black markings, mingled with whitish, denoted eggs near to disclosing adult wasps. The wasps escape from the billbug egg through one or more holes. A few are weaklings, however, and perish within the shell.

The A generation of seven eggs secured from the field in early June produced 41 *Anaphoidea* wasps. These were given a total of 311 billbug eggs, chiefly those of *Calendra parvula, zeae, scoparia* and *maidis,* between June 10 and 22, when the last *Anaphoidea* died. This A generation successfully parasitized approximately 43 of these *Calendra* eggs, that gave rise to a B generation of 189 wasps. From June 25 to July 6, this generation was offered about 1,400 billbug eggs, mainly *C. maidis,* a large species that lays an egg much larger than that of our sugar cane borer, and that proved the most available as well as otherwise the most satisfactory billbug to work with. The C generation resulting amounted to about 100 parasitized billbug eggs. Most of these eggs were kept in the comparatively cool cellar for a time so that the wasps would not hatch too soon, otherwise some of their earlier progeny (D generation) might issue during the Missouri-Hawaii journey. From July 15 to July 21, the day of departure from Missouri, a total of about 2,000 eggs of *Calendra maidis* were exposed to the several hundred wasps that issued from the 100 or so parasitized eggs. The results were rather disappointing, as the D generation was only slightly greater than C, and only so because practically all parasitized eggs were large eggs, and perhaps a greater percentage of them hatched successfully. The first parasitized eggs of this D generation were kept in refrigeration for from one to two days, to retard their development, for at that time the temperature at Webster Groves ranged around 90° F. and some eggs in the warmer part of the laboratory were collapsing. This lot of slightly over 100 parasitized maize billbug eggs was readily transported to Hawaii in depressions in moist clay in metal salve boxes, the first *Anaphoidea* issuing on the morning of August 2, the day after their arrival at Paauhau Sugar Plantation. By the afternoon of August 6, some 700 wasps had hatched. These were promptly liberated in cane fields Nos. 6 and 14A of this plantation, and where conditions seemed best for their success, beetle borers being present there in plenty and traps consisting of pieces of sugar cane, split or intact, having been placed therein to concentrate the borers and thus, too, their eggs.

While at Paauhau, I offered about a dozen fresh beetle borer eggs to a large number of *Anaphoidea* parasites, the offering being distributed over three days. Contrary to my expectations, the wasps were very indifferent to these beetle borer eggs, in striking contrast to the behavior of many of them towards billbug eggs in Missouri. None of these twelve cane borer eggs produced parasites. Possibly, however, conditions in the canefields may prove more inviting to *Anaphoidea.* A certain number of eggs of the lot D did not produce wasp parasites until after my departure, on August 4, from Paauhau. Instructions were left, however, to liberate whatever wasps hatched therefrom in field 14A. About 40 wasps were also turned loose in the Manoa Substation cane, Honolulu, on August 7.

As a secondary project, 102 adults of *Scarites,* a more or less subterranean ground beetle—the larva dwelling entirely underground—were collected under stones, logs, etc., at Webster Groves, and were mailed as well as brought in to Honolulu and released in field No. 41, Oahu Sugar Company, in the hope that these predaceous insects will become established and prey upon the grubs of *Adoretus sinensis,* the Chinese rose beetle.

Finally, a total of eight females and seven males of *Rhinopsis caniculatus,* a wasp that in Missouri parasitizes certain native wood cockroaches (*Parcoblatta*), and in the laboratory in Honolulu found also to prey upon *Loboptera sakalava,* one of our commonest field roaches, as does likewise *Dolichurus stantoni,* the Philippine roach wasp now established in the Hawaiian Islands, were liberated August 8, below the Nuuanu Pali, and at the Manoa Substation.

In Farmers' Bulletin 1003, United States Department of Agriculture, January, 1919, and written by A. F. Satterthwait, is a brief and well illustrated treatise on billbugs and their control.

Anaphoidea calendrae, the billbug egg parasite, is described by Gahan in the Proceedings of the United States National Museum, Vol. 71, pp. 32-35, Fig. 2, 1928.

Molasses, Press Cake, Bagasse, and Ash Mixtures as Fertilizer

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By J. A. Verret and R. E. Doty

Soil Used

This work was carried on at Makiki in a series of concrete tubs holding eight cubic feet of soil each. The soil used was a poor mauka one obtained at the Manoa substation.

The department of chemistry gives the composition of this soil as follows:

	1 Per cent Citric Acid Soluble				Strong HCl Soluble			Total by Fusion		
Soil Reaction pH	Silica SiO_2	Lime CaO	Potash K_2O	Phos. Acid P_2O_5	Lime CaO	Potash K_2O	Phos. Acid P_2O_5	Potash K_2O	Phos. Acid P_2O_5	Nitrogen N
5.3	0.10	0.49	0.062	0.0033	0.94	0.11	0.14	0.36	0.26	0.28

From the above we see that this soil is decidedly acid and has a low content of available phosphate. There is a good supply of available potash in the soil, but there is a slightly low content of total reserve potash and phosphates.

Composition of the Mixture (Molasses Cake*)

The mixture used had the following composition by weight:

Molasses	48.5 per cent
Press cake	33.8 per cent
Bagasse	12.2 per cent
Ashes	5.5 per cent

Its analysis follows:

0.40 per cent nitrogen	8 pounds per ton
0.81 per cent phosphoric acid	16 pounds per ton
2.65 per cent potash	53 pounds per ton
1.09 per cent lime	22 pounds per ton

The main object in making this mixture is to facilitate the transportation of the molasses. To many poor, mauka fields which are likely to be most in need of molasses treatments, it is not practical to transport molasses as such. When incorporated in a mixture as above it becomes purely a matter of cost versus the benefits to be derived.

Details of Application and Treatments Given

Where it is cheaper to put the molasses and press cake separately on fields which are to be plowed, we, as yet, see no reason why it should not be done instead of going to the extra expense of making the mixture.

When used the molasses mixture was well incorporated in the top foot of soil only.

Three-eye cuttings from which the two end eyes had been gouged out were used for seed. These were started in germinating trays and when planted in the tubs every care was taken to use plants of uniform size.

This pot test can be used only as an indicator of the trend of results, as the number of large sized pots was necessarily so limited that proper repetition was impossible. Therefore, we should keep its limitations in mind as we study the following data:

* This term is applied to a mixture of molasses, filter press cake, bagasse, and furnace ash.

TABLE I

The treatments given the various tubs are shown in the following tabulation:

Tub	Treatment at planting time	Fertilizer applied 56 days after planting	Fertilizer applied $3\frac{1}{2}$ mos. after planting	Total pounds P.A. N	P_2O_5	K_2O
Tub 2	Check—no treatment	....	100 lbs. N; 100 lbs. P_2O_5; 100 lbs. K_2O	100	100	100
4	" " "	....		100	100	100
Tub 1	Molasses cake 20 T.P.A....	....	No treatment	160	320	1060
3	" " " " ...	....	100 lbs. N	260	320	1060
Tub 5	Molasses cake 20 T.P.A....	100 lbs. N; 100 lbs. P_2O_5; 100 lbs. K_2O	No treatment	260	420	1160
7	" " " " ...		100 lbs. N	360	420	1160
Tub 6	No molasses cake.........	100 lbs. N; 100 lbs. P_2O_5; 100 lbs. K_2O	No treatment	100	100	100
14	" " "		100 lbs. N	200	100	100
Tub 19	Molasses cake 5 T.P.A.....	....	No treatment	40	80	265
22	" " " "	....	100 lbs. N	140	80	265
Tub 18	....	Molasses cake 5 T.P.A.	No treatment	40	80	265
20	....	Molasses cake 5 T.P.A.	100 lbs. N	140	80	265
Tub 21	....	Molasses cake 5 T.P.A. + 100 N; 100 P_2O_5 + 100 K_2O	No treatment	140	180	365
23	....		100 lbs. N	240	180	365

Tub	Treatment applied 2 months before planting	Fertilizer applied 56 days after planting	Fertilizer applied $3\frac{1}{2}$ mos. after planting	Total pounds P.A. N	P_2O_5	K_2O
Tub 9	Check—no treatment	....	....	...	...	....
11	" " "	....	....	...	...	....
Tub 8	Molasses cake 20 T.P.A....	....	No treatment	160	320	1060
10	" " " " ...	....	100 lbs. N	260	320	1060
Tub 12	Molasses cake 20 T.P.A....	100 lbs. N; 100 lbs. P_2O_5; 100 lbs. K_2O	No treatment	260	420	1160
15	" " " " ...		100 lbs. N	360	420	1160
Tub 13	Molasses cake 20 T.P.A....	....	No treatment	260	420	1160
16	100 N; 100 P_2O_5; 100 K_2O.	....	100 lbs. N	360	420	1160
Tub 17	Molasses cake 40 T.P.A....	....	No treatment	320	640	2120
24	" " " " ...	....	100 lbs. N	420	640	2120

Table II

The treatments including total plant food applied as commercial fertilizer with the harvesting weights are given in the following table:

Treatment at planting time Amounts of molasses cake only listed		Total plant food applied. Obtained from molasses cake and chemical fertilizer together N	P_2O_5	K_2O	Harvested Sept. 20, 1928—age 7 mos. 24 days Millable Cane	Total weight of green material
Tub 2	Check—no molasses cake.......	100	100	100	379	921
4	" " " "	100	100	100	1120	2044
Tub 1	Molasses cake 20 T.P.A.........	160	320	1060	239	916
3	" " " "	260	320	1060	1852	2817
Tub 5	Molasses cake 20 T.P.A.........	260	420	1160	1624	2807
7	" " " "	360	420	1160	5122	7855
Tub 6	No molasses cake..............	100	100	100	422	820
14	" " "	200	100	100	3095	4875
Tub 19	Molasses cake 5 T.P.A.........	40	80	265	544	1159
22	" " " "	140	80	265	1543	2636
Treatments 56 days after planting:						
Tub 18	Molasses cake 5 T.P.A.........	40	80	265	564	1028
20	" " " "	140	80	265	2470	3954
Tub 21	Molasses cake 5 T.P.A.........	140	180	365	328	779
23	" " " "	240	180	365	3765	5607
Treatments applied 2 months before planting:						
Tub 9	Check—no treatment...........	...	...	....	209	688
11	" " "	...	...	....	262	642
Tub 8	Molasses cake 20 T.P.A.........	160	320	1060	1022	1924
10	" " " "	260	320	1060	3435	5921
Tub 12	Molasses cake 20 T.P.A.........	260	420	1160	2592	4014
15	" " " "	360	420	1160	9775	13157
Tub 13	Molasses cake 20 T.P.A.........	260	420	1160	1385	2314
16	" " " "	360	420	1160	5470	8274
Tub 17	Molasses cake 40 T.P.A.........	320	640	2120	1234	2297
24	" " " "	420	640	2120	4102	6486

Time of Application of Molasses Cake

In the table given below we have segregated the pots and yields according to whether the molasses cake was put on at planting time or two months before planting. Other fertilization was uniform for the corresponding pairs.

Table III

Molasses cake at planting time Tub No.	Millable cane gms.	Total weight of green material	Molasses cake 2 months before planting Tub No.	Millable cane gms.	Total weight of green material
1	239	916	8	1022	1924
3	1852	2817	10	3435	5921
5	1624	2807	12	2592	4014
7	5122	7855	15	9775	13,157
Total	8837	14,395	Total	16,824	25,016
Average ...	2209	3599	Average ..	4206	6254
Gain				1997	2655
Gain per cent				90.4	73.8

These figures show significant gains in favor of applying the molasses cake two months before planting.

This is in line with results obtained in other places when working with molasses. Under most conditions it has been found more satisfactory to apply the molasses before planting rather than on the growing crop.

In Hawaii recent trials have shown marked response on the part of sugar cane when the molasses was applied with the first water after planting. In other cases the same procedure has lowered germination and checked early growth. It is unquestioned that it is a better procedure to apply the molasses as early as possible; before planting in the case of fields to be plowed.

The reason for the check in growth which often occurs when molasses is applied to a growing crop is believed to be due to the fact that in decomposing, the molasses has a denitrifying action on the nitrates in the soil. The reaction is much stronger on some soils than on others.

In the test being reported we had a gain of approximately 75 per cent in favor of the early application. These results are significant in that there were no exceptions, that is, all pots which received the molasses cake two months before planting produced much larger yields than those to which the mixture was applied later, as shown in Table III. (See Fig. 1.)

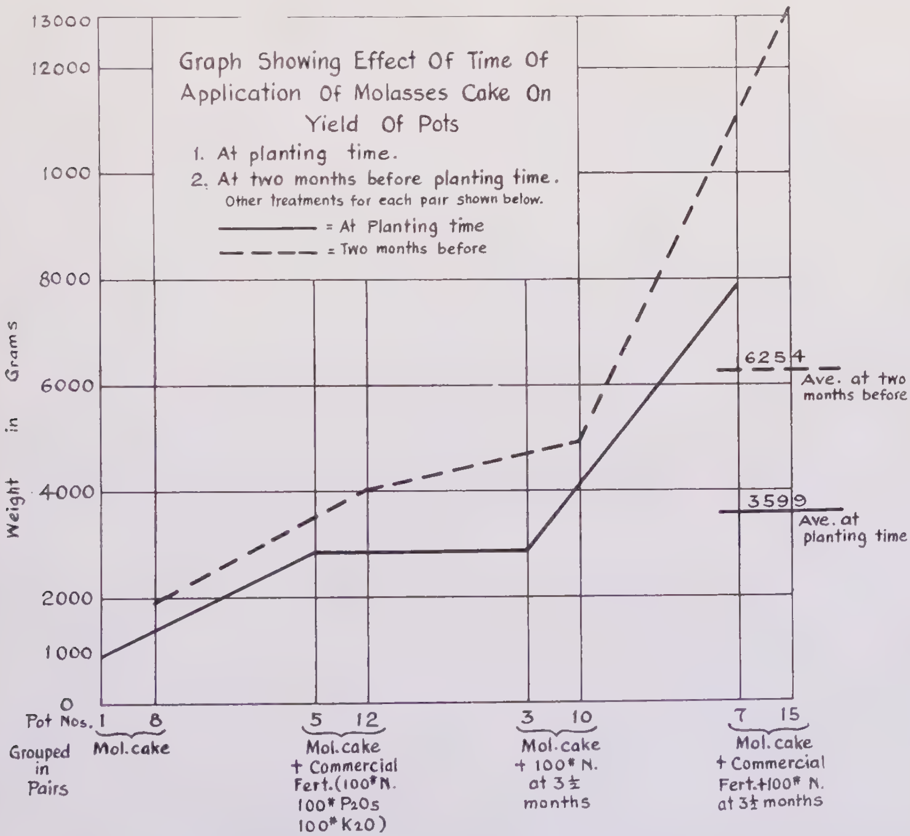

Fig. 1

Time of Molasses Cake Application in Connection With Complete Fertilizer

The time of application of the molasses cake and commercial fertilizer has a definite effect on the growth as illustrated in the tabulation below:

Table IV

Molasses cake late (planting time); fertilizer late (56 days after planting)

Pot No.	Total plant food N	Total plant food P_2O_5	Total plant food K_2O	Millable cane	Total green weight
5	260	420	1160	1624	2807
7	360	420	1160	5122	7855
Average				3373	5331

Both molasses cake and fertilizer applied early (2 months before planting)

Pot No.	Total plant food N	Total plant food P_2O_5	Total plant food K_2O	Millable cane	Total green weight
13	260	420	1160	1385	2314
16	360	420	1160	5470	8274
Average				3427	5289

Molasses cake early (2 months before planting); fertilizer late

Pot No.	Total plant food N	Total plant food P_2O_5	Total plant food K_2O	Millable cane	Total green weight
12	260	420	1160	2592	4014
15	360	420	1160	9775	13157
Average				6183	8595

In Table IV we show the effect of time of application of the various ingredients when both molasses cake and commercial fertilizers are used.

The best results were obtained when the molasses cake was applied two months before planting and the fertilizer two months after. Next was when both the molasses cake and fertilizer were applied two months before planting. These results were closely approximated when the molasses cake was applied at planting time and the fertilizer two months later.

Molasses Cake and Commercial Fertilizer

Table V-A

	No treatment			Molasses cake 20 T.P.A. only Plant food equivalent (160 N, 320 P_2O_5, 1060 K_2O)	
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
9	209	688	8	1022	1924
11	262	642	1	239	916
Totals	471	1330	Totals	1261	2840
Average	235	665	Average	630	1420
Gain produced by molasses cake.....................				395	755
Gain in per cent..................................				168	113

Table V-B

	No treatment			Complete fertilizer + no molasses cake + 100 lbs. N to No. 14⊕	
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
9	209	688	6	422	820
11	262	642	14⊕	3095	4875
			4	1120	2044
Total	471	1330	Total	4637	7739
Average	235	665	Average	1545	2579
Gain due to commercial fertilizer over check..........				1310	1914
Gain in per cent..................................				557	288

Table V-C

	No treatment			Complete fertilizer + molasses cake 20 T.P.A. + 100 lbs. N to No 7⊕	
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
9	209	688	5	1624	2807
11	262	642	7⊕	5122	7855
			12	2592	4014
Total	471	1330	Total	9338	14,676
Average	235	665	Average	3113	4892
Gain due to commercial fertilizer + 20 T.P.A. molasses cake				2878	4227
Gain in per cent..................................				1224.6	636

Summary of Tables V-A, V-B, V-C

Gain of 20 T.P.A. molasses cake over no treatment	113 per cent
Gain of commercial fertilizer (133 lbs. N, 100 lbs. P_2O_5, 100 K_2O) over no treatment	288 per cent
Gain of 20 T.P.A. molasses cake and commercial fertilizer (133 lbs. N, 100 lbs. P_2O_5, 100 lbs. K_2O) over no treatment	636 per cent

From the above we note a gain of 113 per cent for 20 T.P.A. of molasses cake over no treatment. The molasses cake used supplied 160 pounds of nitrogen, 320 pounds of phosphoric acid and 1060 pounds of potash per acre. Commercial fertilizer containing 133 pounds of nitrogen, 100 pounds of phosphoric acid and 100 pounds potash per acre produced a gain of 288 per cent over no treatment.

When both the molasses cake and the fertilizer were used the gain becomes 636 per cent, more than double the gain of either one above. Judging from the gains of each one when used alone we should get a gain of about 400 per cent when combined. Instead of that we have over 600 per cent gain, an increase of 50 per cent over what was to be expected. This would indicate that under some conditions the use of molasses or a mixture as above, is not only of direct benefit, but increases the value of the other fertilizer used. (See Fig. 2.)

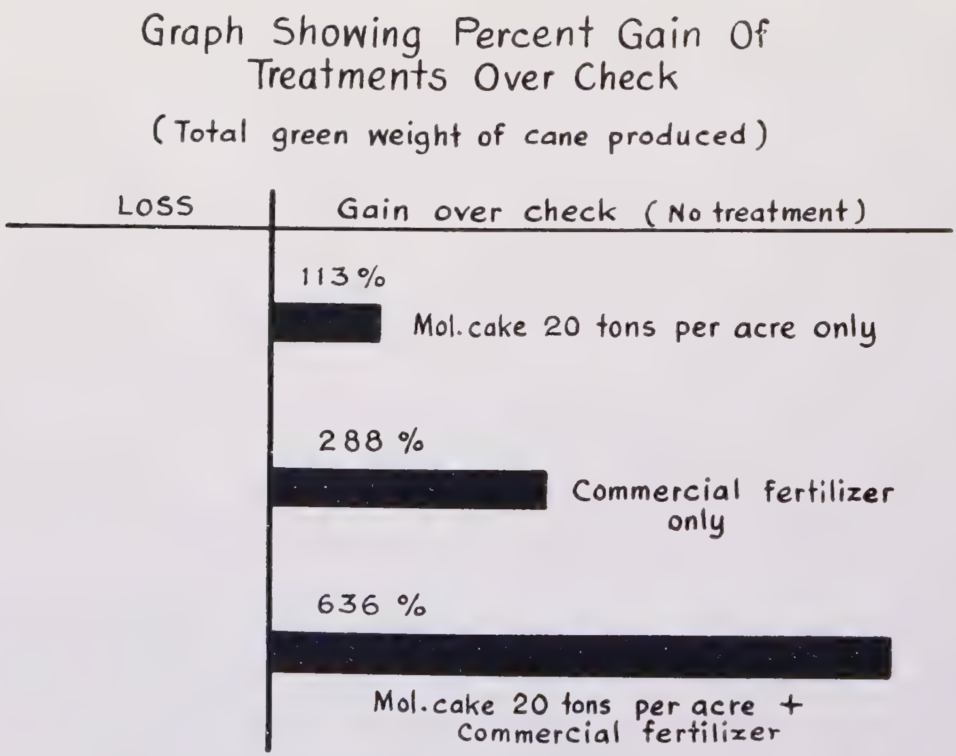

Fig. 2

Extra Nitrogen

In Table VI we show the effect of adding 100 pounds per acre of nitrogen when the cane was 3½ months of age. All other treatments were the same for the tubs compared. That is, each pair of tubs 1 and 3, 5 and 7, etc., received the same treatment except for the 100 pounds of nitrogen.

Table VI

	No nitrogen at 3½ months			100 lbs. nitrogen at 3½ months	
Tub No.	Millable cane gms.	Total weight gms.	Tub No.	Millable cane gms.	Total weight gms.
1	239	946	3	1852	2817
5	1624	2807	7	5122	7855
6	422	820	14	3095	4875
19	544	1159	22	1543	2636
18	564	1028	20	2470	3954
21	328	779	23	3765	5607
8	1022	1924	10	3435	5921
12	2592	4014	15	9775	13157
13	1385	2314	16	5470	8274
17	1234	2297	24	4102	6486
Total	9954	18,058	Total	20,629	61582
Average	995.4	1805.8	Average	4062.9	6158.2
Gain				3067.5	4352.4
Gain in per cent				308.1	241.0

The increases from this nitrogen were in all cases very large. Even tubs which had already gotten 160 pounds of nitrogen per acre from molasses cake and 100 pounds from complete fertilizer responded. See tubs Nos. 7, 14, 15 and 16.

This would indicate that the nitrogen in molasses cake is not readily available and should be supplemented with soluble forms from other fertilizer. (See Fig. 3.)

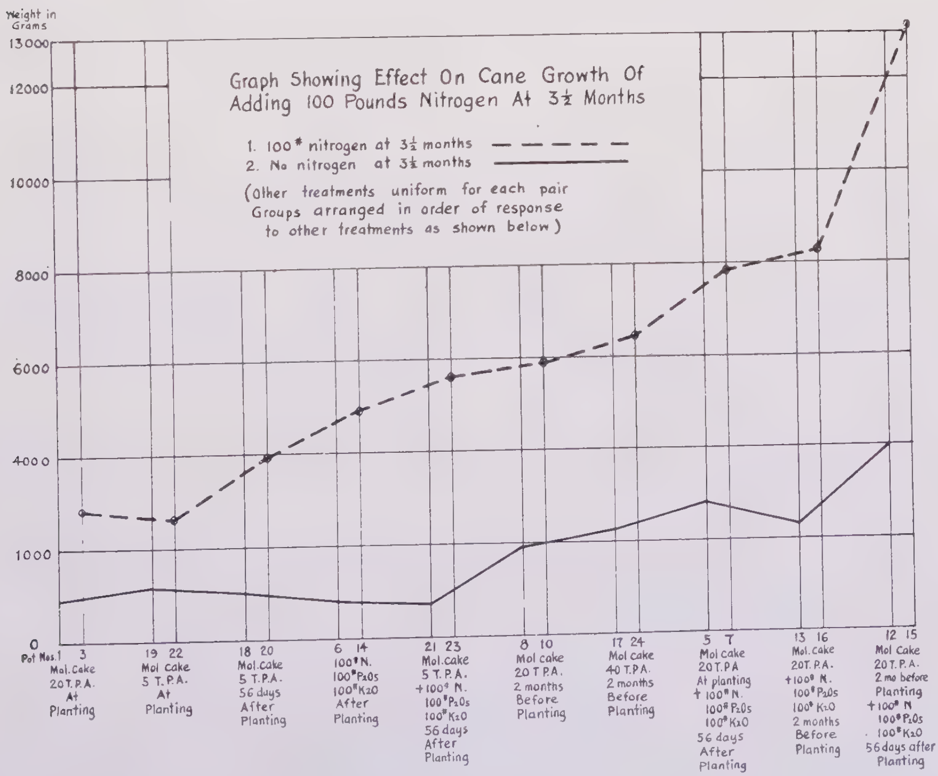

Fig. 3

Fig. 4

No. 15

1. Molashcake 20 T. P. A. applied 2 months before planting.
2. Complete fertilizer, 100 lbs. of each element applied 56 days after planting.
3. 100 lbs. of N applied at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane .....9775 grams
Trash and Leaves..3382 grams

Total ....13,157 grams

No. 14

1. No treatment at or before planting.
2. Complete fertilizer, 100 lbs. of each element applied 56 days after planting.
3. 100 lbs. of N applied at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane .....3095 grams
Trash and leaves..1780 grams

Total ....4875 grams

No. 13

1. Molashcake 20 T. P. A. + complete fertilizer, 100 lbs. of each element applied 2 months before plantng.
2. No further treatment.

Weights at 7 mos. 24 days

Millable cane .....1385 grams
Trash and leaves.. 929 grams

Total ....2314 grams

Fig. 5

No. 12

1. Molashcake 20 T. P. A. applied 2 months before planting.
2. Complete fertilizer, 100 lbs. of each element applied at 56 days after planting.
3. No treatment at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane	2592 grams
Trash and leaves..	1422 grams
Total	4014 grams

No. 11

Check—no treatment at any period.

Weights at 7 mos. 24 days

Millable cane	262 grams
Trash and leaves..	380 grams
Total	642 grams

No. 10

1. Molashcake 20 T.P.A. applied 2 months before planting.
2. No treatment at 56 days after planting.
3. 100 lbs. N at 3½ months after planting.

Weights at 7 mos. 24 days

Millable cane	3435 grams
Trash and leaves..	2486 grams
Total	5921 grams

Soil Reaction

After the canes were harvested, the soil in each tub was sampled and the reaction determined by the chemistry department.

The results are given in Table VII.

Table VII

MOLASSES CAKE EXPERIMENT—MAKIKI EXPERIMENT 8—TREATMENTS

Tub No.	At planting time	Fertilizer applied 56 days after planting	Fertilizer applied 3½ months after planting	Soil reaction pH
2	No treatment	....	100 lb. N, 100 lb. K_2O	7.17
4	" "	....	100 lb. P_2O_5	6.95
1	Molasses cake 20 T.P.A.	....	No treatment	7.13
3	" " " "	....	100 lb. N	6.88
5	Molasses cake 20 T.P.A.	100 lb. N, 100 lb. K_2O,	No treatment	7.12
7	" " " "	100 lb. P_2O_5	100 lb. N	6.59
6	No treatment	100 lb. N, 100 lb. K_2O,	No treatment	6.44
14	" "	100 lb. P_2O_5	100 lb. N	6.59
19	Molasses cake 5 T.P.A.	....	No treatment	6.59
22	" " " "	....	100 lb. N	7.00
18	No treatment	Molasses cake 5 T.P.A.	No treatment	7.13
20	" "	" " " "	100 lb. N	7.13
21	No treatment	100 lb. N, 100 lb. K_2O,	No treatment	6.78
23	" "	100 lb. P_2O_5, Molasses cake 5 T.P.A.	100 lb. N	6.56
9	No treatment	....	No treatment	6.75
11	" "	....	100 lb. N	6.75
8	Molasses cake 20 T.P.A.	....	No treatment	6.81
10	" " " "	....	100 lb. N	7.17
12	Molasses cake 20 T.P.A.	100 lb. N, 100 lb. K_2O,	No treatment	6.75
15	" " " "	100 lb. P_2O_5	100 lb. N	6.58
13	Molasses cake 20 T.P.A.	....	No treatment	6.58
16	100 lb. N, 100 lb. K_2O 100 lb. P_2O_5	....	100 lb. N	6.32
17	Molasses cake 40 T.P.A.	....	No treatment	6.26
24	" " " "	....	100 lb. N	6.68

Although all the soils are much less acid than at the beginning of the test, there seems to be no distinction due to the various treatments.

Mr. Hansson, of the chemistry department, makes the following comment:

Twelve different treatments were tried with two tubs for each treatment. The fertilization and reaction of the soil in each tub is given in Table VII. The soil used came from our Manoa lands and had an original reaction of pH 5.3. Tubs Nos. 9 and 11, which have received no treatment of any sort, are less acid than at the start of the experiment. They now have a pH of 6.75. This would point to a possible change in reaction, as the result of irrigation with hydrant water. The hydrant water contains moderate amounts of replaceable calcium and this increase in pH would suggest that some replacement has occurred. It is also quite possible that some of the decrease in the acidity of the soil was brought about by permitting it to dry out and aereate before being used in the tubs.

Although there is some variation in the reaction of the soil in the various tubs, there appear to be no distinctive differences. The nitrogen was applied as nitrate of soda.

A Pipe Line Water Meter

A device for measuring water, which seems well adapted to local conditions, is that manufactured by the R. W. Sparling Company, of Los Angeles. The meter is adapted to pipe lines only, and is built for any pipe line, four inches or larger, and for any pressure up to 100 pounds per square inch.

Briefly, the Sparling meter consists of a propellor-shaped fan, mounted crosswise in a pipe. The fan runs on ball bearings, and drives through worm and spur gears to a registering counter. The propeller fans are constructed of cast aluminum alloy; fan shafts, cones, ball races, balls, worms and gears of Monel metal (a hard, non-corrosive alloy of copper and nickel); gear boxes, compensating gears, counters, and register boxes are of brass or bronze.

H. A. Wadsworth, of the University of Hawaii, who has seen this meter in operation, states that it is excellently constructed, is accurate, and has proved very satisfactory in California.

Waianae Company has two of these meters installed on pump discharge lines, and states that they have given satisfactory service. These meters seem particularly well adapted to small pump units, such as booster pumps with a 2 to 4 million gallon discharge, where it would not be economically profitable to install an expensive Venturi meter, but where a record of pump discharge is desired.

DATA ON SPARLING METER

	Minimum Flow		Maximum Flow		Price, F. O. B., L. A.	
Size	Sec. Ft.	Gallons/Min.	Sec. Ft.	Gallons/Min.	Regular	Heavy
4″	0.22	100	0.56	250	$ 80.00	$100.00
6″	0.28	125	1.23	550	100.00	125.00
8″	0.33	150	2.23	1,000	120.00	150.00
10″	0.39	175	3.79	1,700	140.00	175.00
12″	0.49	220	5.90	2,650	160.00	200.00
14″	0.60	270	8.47	3,800	180.00	225.00
16″	0.72	325	10.58	4,750	200.00	250.00
18″	0.96	430	13.37	6,000	220.00	275.00
20″	1.28	575	20.06	9,000	240.00	300.00
24″	1.67	750			280.00	350.00
30″	2.67	1,200			.....	425.00
36″	3.57	1,600			.....	500.00
48″	5.35	2,400			.....	650.00

H. R. S.

Fungicidal Dust Tests Against Eye Spot During the 1927-1928 Eye Spot Season*

By J. P. Martin

The results from the experimental research conducted with fungicidal dusts against eye spot during the 1926-1927 eye spot season were sufficiently encouraging to warrant further studies the following season. Two points were established: First, the addition of potassium permanganate as an oxidizing agent at the rate of one per cent to dusting sulphur, gave much better control of the disease when applied at weekly intervals than had been obtained before. Secondly, it was found that when calcium hydrate was used as a carrier the disease increased rapidly and the eye spot counts were greater than those from the check plots or plots receiving no dust treatment. Apparently the calcium hydrate saponified to a large extent the wax on the surface of the cane leaf, thus making it an easy matter for the fungus to penetrate the young cane leaf. It was necessary to discontinue the use of several dusts with a lime base long before the peak of the eye spot season was reached because of the sudden increase of eye spot.

With the above information it was decided to use a fine grade of dusting sulphur as the carrier for all dusts. Since sulphur plus one per cent of potassium permanganate gave such a good control of the disease, it was planned to add other oxidizing agents to sulphur, such as manganese dioxide and lead dioxide.

In fungicidal work "stickers" are often added to dusts and sprays in order that the dusts or liquid sprays may adhere better to the foliage. Upon this basis dextrin and gum tragacanth were added at the rate of one per cent to sulphur plus one per cent of potassium permanganate.

With the above knowledge the following dusts were planned by H. A. Lee and the writer to be tested during the 1927-1928 eye spot season:

Dust No.	Dust Letter	Mixture of Dust			
1	A	Sulphur			
2	B	"	plus 5%	$KMnO_4$	
3	C	"	" 1%	"	
4	D	"	" 5%	MnO_2	
5	E	"	" 5%	PbO_2	
6	F	"	" 1%	$KMnO_4$	plus 4% MnO_2
7	G	"	" 1%	"	" 1% Dextrin
8	H	"	" 1%	"	+ 1% gum tragacanth
2	I	"	" 5%	"	
3	J	"	" 1%	"	

In Field Kemoo 1 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 1. Dusts A, B, D, E and F were applied every two weeks,

* Reprinted from last number to include illustrations omitted in that issue.

FUNGICIDAL DUSTS IN RELATION TO EYE SPOT

W. A. Co. Ltd., Field Kemoo 1; 1st Ratoon, H 109 Cane

6 X Plots	Controls, No Treatment	
6 A "	Sulfur	
6 B "	" plus	5% $KMnO_4$
6 D "	" "	5% MnO_2
6 E "	" "	5% PbO_2
6 F "	" "	1% $KMnO_4$ plus 4% MnO_2
6 I "	" "	5% $KMnO_4$

Dusts A, B, D, E and F were applied every two weeks.
Dust I was applied weekly.
First Application of all Dusts October 28, 1927

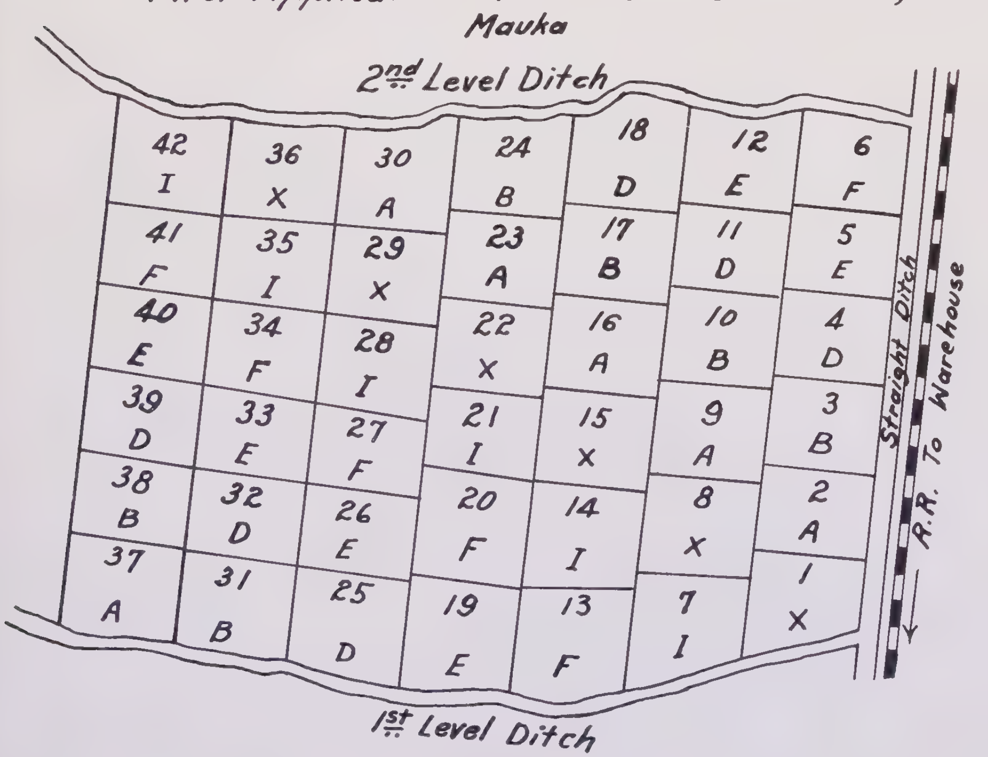

Fig. 1

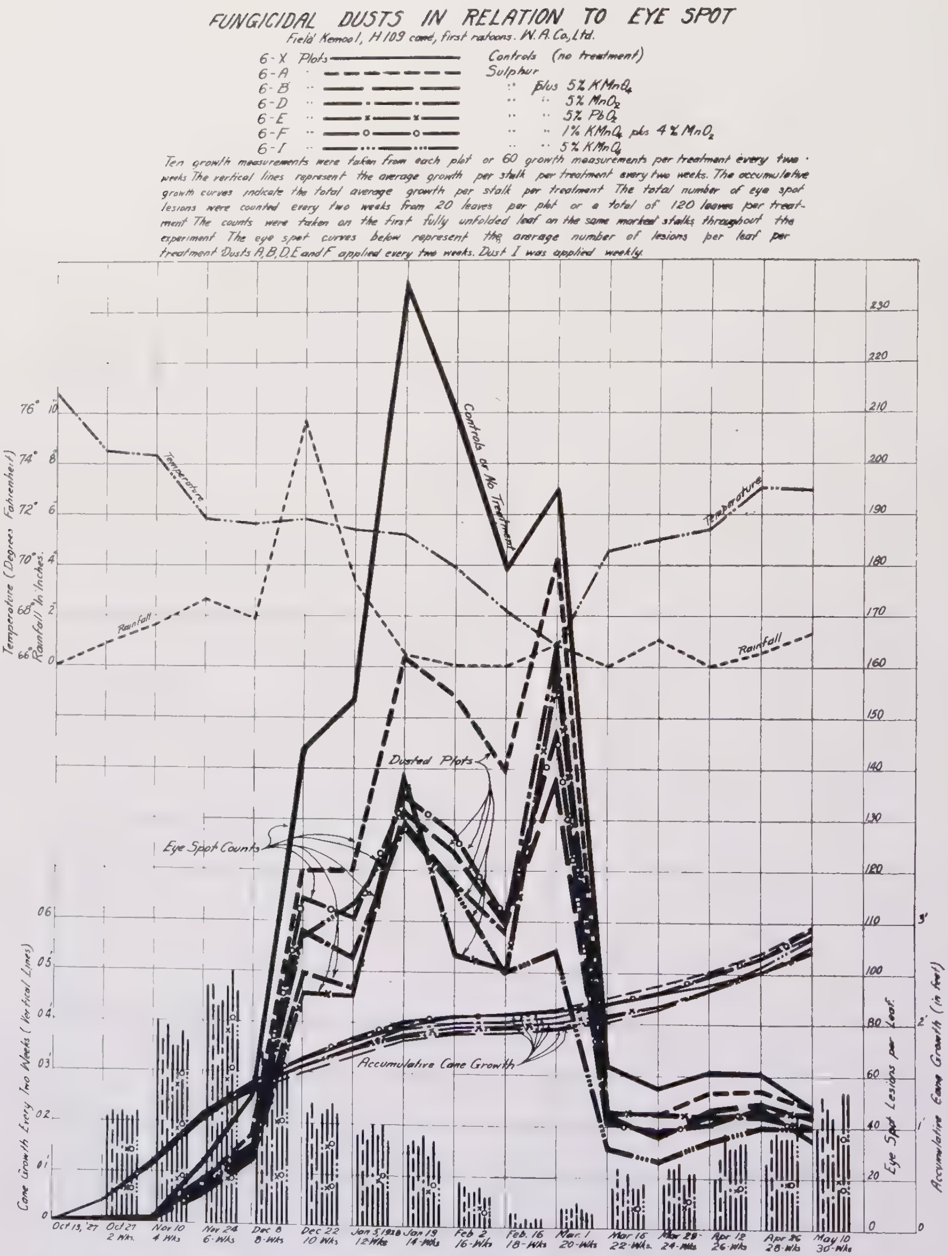
FUNGICIDAL DUSTS IN RELATION TO EYE SPOT
Field Kemool, H 109 cane, first ratoons. W. A. Co., Ltd.
6-X Plots — Controls (no treatment)
6-A — Sulphur
6-B — plus 5% KMnO4
6-D — 5% MnO2
6-E — 5% PbO2
6-F — 1% KMnO4 plus 4% MnO2
6-I — 5% KMnO4
Ten growth measurements were taken from each plot or 60 growth measurements per treatment every two weeks. The vertical lines represent the average growth per stalk per treatment every two weeks. The accumulative growth curves indicate the total average growth per stalk per treatment. The total number of eye spot lesions were counted every two weeks from 20 leaves per plot or a total of 120 leaves per treatment. The counts were taken on the first fully unfolded leaf on the same marked stalks throughout the experiment. The eye spot curves below represent the average number of lesions per leaf per treatment. Dusts A, B, D, E and F applied every two weeks. Dust I was applied weekly.
Temperature (Degrees Fahrenheit)
Rainfall in Inches
Temperature
Rainfall
Controls or No Treatment
Dusted Plots
Eye Spot Counts
Accumulative Cane Growth
Cane Growth Every Two Weeks (Vertical Lines)
Eye Spot Lesions per Leaf
Accumulative Cane Growth (in feet)
Oct 13, '27
Oct 27 2 Wks
Nov 10 4 Wks
Nov 24 6 Wks
Dec 8 8 Wks
Dec 22 10 Wks
Jan 5, 1928 12 Wks
Jan 19 14 Wks
Feb 2 16 Wks
Feb 16 18 Wks
Mar 1 20 Wks
Mar 15 22 Wks
Mar 29 24 Wks
Apr 12 26 Wks
Apr 26 28 Wks
May 10 30 Wks
J PM. 6-28.

Fig. 2

while Dust I was applied weekly, beginning October 28, 1927. There were six repetitions of each fungicidal dust treatment and six check plots that received no treatment. No further dust applications were applied after February 9, 1928, which was after the peak of the eye spot season.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 120 leaves were counted every two weeks from each treatment. In every case eye spot counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The average number of eye spot lesions per leaf from each treatment is shown in Fig. 2 by the heavy curves labeled eye spot counts.

The word *control* as used throughout this article signifies the difference for each treatment between the average number of lesions or infections per leaf of the treated and of the non-treated plots. The difference is secured by comparing quantitative calculations as explained in the preceding paragraph. This is not to be confused with the more practical definition of the word *control* as applied to plant diseases which compares the increase in yield of any crop due to special treatment with the yield obtained from similar plots or areas not receiving special treatment.

The object of applying fungicidal dusts to cane is to have a coating of the dust on the leaves at all times during the winter months so that the spores of the fungus upon germination are immediately killed as soon as they come in contact with the dust, thus preventing their entrance to the leaf. Once the fungus has penetrated the leaf a dust or spray that would be toxic to the development of the organism within the leaf tissue would also be very injurious to the cane plant itself. To maintain such a coating of dust on the cane foliage during the rainy season it would be necessary to apply such dusts to the susceptible areas from two to three times a week. These numerous applications would be prohibitive on a plantation basis because of the expense that would be involved.

The damage on cane leaves resulting from eye spot is not in direct proportion to the number of infections. The seriousness of the disease depends largely on the location of the infections in the leaf itself. From each infection large runners or streaks develop, extending from the initial infection, up the vascular system, to the edge of the leaf. The tissue killed by the so-called runner is oftentimes a hundred times greater than the tissue killed by the primary infection. If ten lesions occur on a single leaf so that ten separate runners are formed, the damage is much greater than if ten lesions occur on another leaf with only five runners formed, due to the fact that certain of the infections fall within the streaks extending from lower infections on the leaf. Therefore, 50 lesions may produce the same amount of damage as 100 lesions.

Ten growth measurements were taken at two-week intervals from each plot, and the average growth per stalk per treatment is presented in Fig. 2 by the vertical lines. The accumulative cane growth from each treatment is also presented in Fig. 2 for the duration of the experiment, which was thirty-eight weeks.

The peak of the eye spot season occurred on January 19, 1928, and the per cent of control from each dust at that date was as follows:

Dust	Per Cent Control
A	31
B	44
D	45
E	41
F	43
I	46

A control with each fungicidal dust was maintained during the eye spot season, as shown in Fig. 2. On January 19, 1928, the lesions per leaf in the dusted plots varied from 128 to 161 as compared to 235 per leaf on the plots receiving no dust treatment. Field observations at this date showed that all plots were badly affected with eye spot, but a fair control was evident on the dusted plots.

The addition of "stickers," such as dextrin and gum tragacanth, did not give an added control of the disease when compared to similar dusts without the "stickers."

In Field Valley 3 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, the remainder of the dusts listed were tested, namely, dusts C, G, H and J, including dust A. In this experiment 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 3. There were seven repetitions of each treatment, and seven check plots which received no dust applications.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 140 leaves were counted every two weeks from each treatment. The counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The results of the various fungicidal dusts A, C, G, H and J, in relation to the control of the disease, are presented in Fig. 4 by the heavy curves labeled eye spot counts.

Ten growth measurements were taken at two-week intervals from each plot and the effect of each dust treatment on the cane growth is shown in Fig. 4, both by the vertical growth curves and the accumulative growth curves.

As illustrated in Fig. 4, a definite control was secured with each fungicidal dust, but no one dust showed exceptional merit. The eye spot counts started to increase rapidly about November 29, 1927, and the peak of the season was reached February 21, 1928. Two other smaller peaks occurred on April 2 and May 1, but the effects of these were negligible. The control from each dust at the peak of the eye spot season, February 21, 1928, was as follows:

Dust	Per Cent Control
J	62
A	55
C	53
G	47
H	47

A decided decrease in the accumulative cane growth was evident on the check plots when compared to the accumulative cane growth from the dusted plots as brought out in Fig. 4. The cane growth on the dusted plots at all times was

FUNGICIDAL DUSTS IN RELATION TO EYE SPOT

W. A. Co. Ltd., Field Valley 3, Plant H109 Cane

7 X	Plots	Controls No Treatment
7 A	"	Sulfur
7 C	"	" plus 1% $KMnO_4$
7 G	"	" " 1% " plus 1% Dextrin
7 H	"	" " 1% " " 1% Gum Tragacanth
7 J	"	" " 1% "

Dusts A, C, G, and H were applied every two weeks
Dust J was applied weekly
First Application of all dusts, Nov. 2, 1927

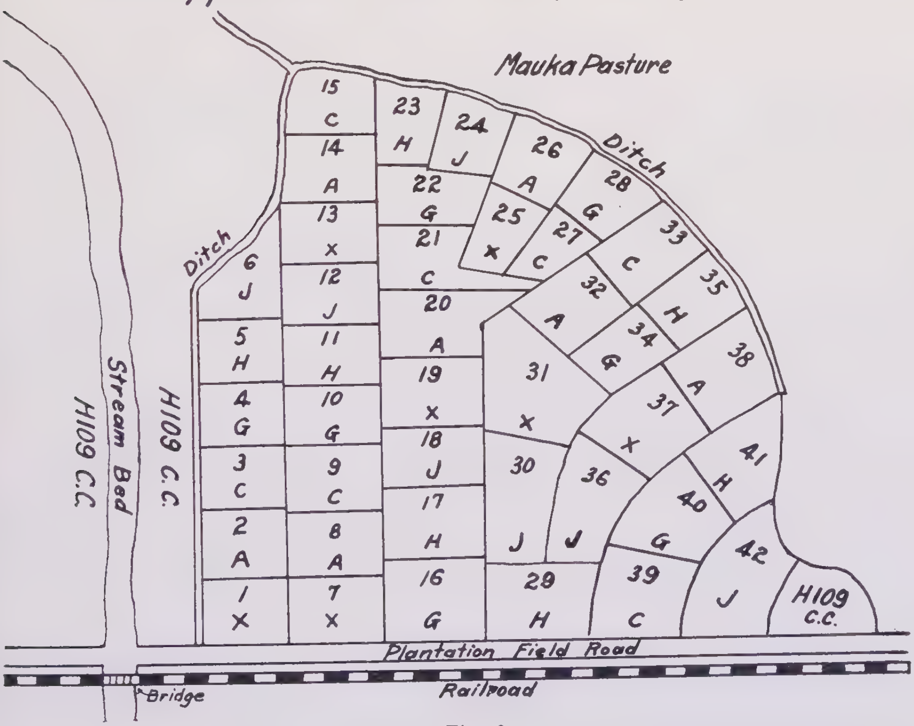

Fig. 3

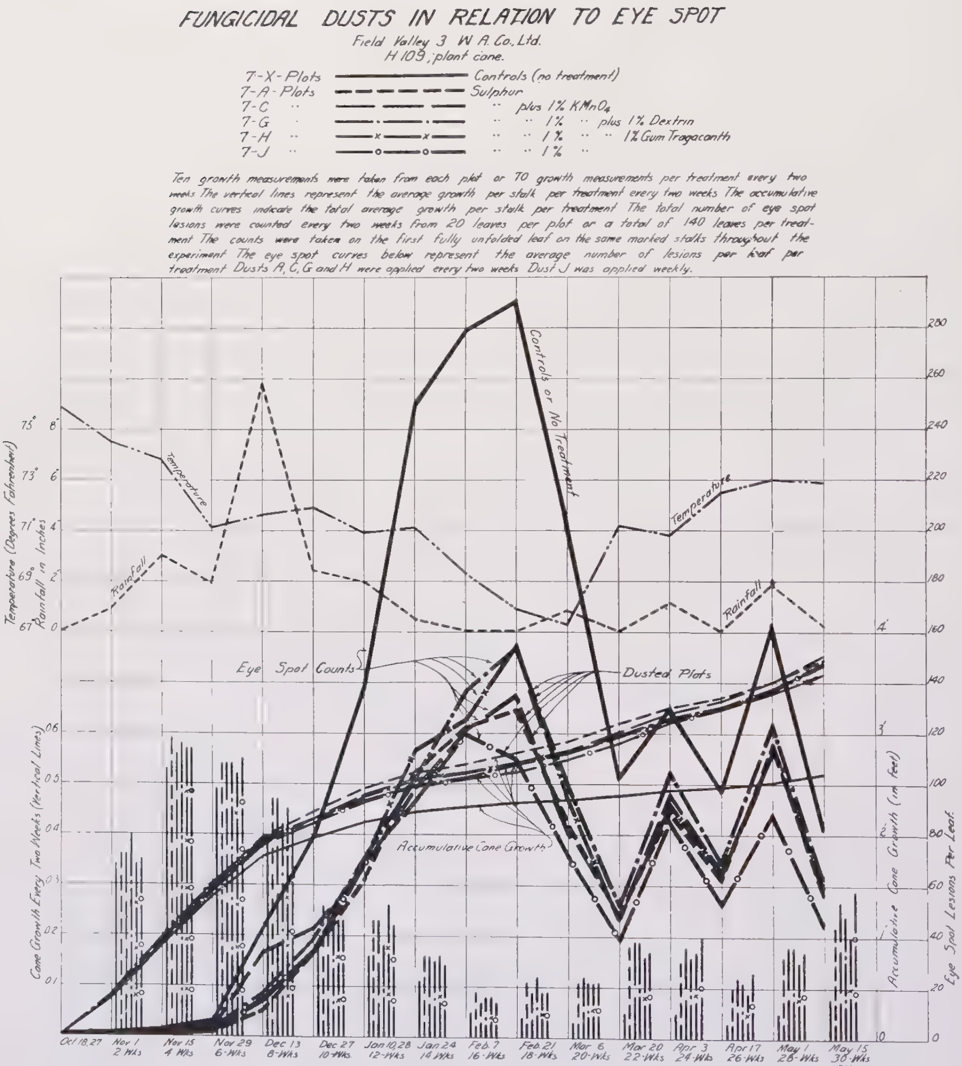
FUNGICIDAL DUSTS IN RELATION TO EYE SPOT
Field Valley 3 W. A. Co., Ltd.
H 109; plant cane.
7-X-Plots Controls (no treatment)
7-A-Plots Sulphur
7-C " " plus 1% KMnO4
7-G " " " 1% " plus 1% Dextrin
7-H " " " 1% " " 1% Gum Tragacanth
7-J " " " 1% "
Ten growth measurements were taken from each plot or 70 growth measurements per treatment every two weeks The vertical lines represent the average growth per stalk per treatment every two weeks The accumulative growth curves indicate the total average growth per stalk per treatment The total number of eye spot lesions were counted every two weeks from 20 leaves per plot or a total of 140 leaves per treatment The counts were taken on the first fully unfolded leaf on the same marked stalks throughout the experiment The eye spot curves below represent the average number of lesions per leaf per treatment Dusts A, C, G and H were applied every two weeks Dust J was applied weekly.
Controls or No Treatment
Temperature
Rainfall
Eye Spot Counts
Dusted Plots
Accumulative Cane Growth
Temperature (Degrees Fahrenheit)
Rainfall in Inches
Cane Growth Every Two Weeks (Vertical Lines)
Accumulative Cane Growth (in feet)
Eye Spot Lesions Per Leaf.
Oct 18, 27
Nov 1 2 Wks
Nov 15 4 Wks
Nov 29 6 Wks
Dec 13 8 Wks
Dec 27 10 Wks
Jan 10, 28 12 Wks
Jan 24 14 Wks
Feb 7 16 Wks
Feb 21 18 Wks
Mar 6 20 Wks
Mar 20 22 Wks
Apr 3 24 Wks
Apr 17 26 Wks
May 1 28 Wks
May 15 30 Wks
J.P.M. 6 28

Fig. 4

practically the same. At the end of the experiment, May, 1928, a difference of one foot of cane growth was observed between the dusted plots and non-dusted plots. This difference was due to the high mortality of individual stalks resulting from top rot in the non-dusted plots.

There appears to have been a very good control from all dusts when expressd in terms of per cent. When leaves average 100 or more eye spot lesions per leaf, another 100 lesions does not add greatly to the present damage to the leaf, but there is a great difference in the control as expressed in per cent. Even though a control varying from 47 to 62 per cent was obtained with the various dusts, it would be necessary to keep the average number of lesions or infections below 60 per leaf in the experimental tests before the dust could be used on a commercial basis.

Of the dusts tested, sulphur plus one per cent of potassium permanganate, when applied at weekly intervals, gave the best control of the disease. This particular dust was also the outstanding one during the preceding eye spot season, and at that time an 89 per cent control was secured.

During the winter months frequent rains are common. In view of the experimental evidence it is necessary to apply the dusts at weekly intervals rather than at two-week intervals because a great deal of dust is washed from the foliage by the rains. It is impossible to apply the dusts at certain periods for two weeks at a time, because of daily showers or rains. Under these conditions the fungus spreads rapidly and the efficacy of any dust against eye spot applied during the winter months depends largely on the rainfall.

In Figs. 2 and 4 the rainfall and temperature are plotted every two weeks for the duration of the experiment, and a direct correlation is observed between temperature and cane growth, and also between rainfall and eye spot counts. With a decrease in temperature there is a decrease in cane growth, and with an increase in temperature there is a corresponding increase in cane growth. With an increase of rainfall there is a marked increase in the eye spot counts, and each eye spot peak, whether large or small, is accompanied by an increase in rainfall. These correlations are brought out by referring to Figs. 2 and 4.

Summary

1. Sulphur plus one per cent of potassium permanganate gave the best control of all the dusts tested. This particular dust was the outstanding dust in last year's experimental work (1926-1927).

2. The interval between two-week applications was too great during the rainy weather. Weekly applications of fungicidal dusts should be maintained during the winter months.

3. The efficacy of any dust against eye spot depends largely on the amount of rainfall and the frequency with which the dust is applied during the very wet weather.

4. Before a dust is tested out on a commercial basis, the average eye spot lesions per leaf should be kept below 60 at all times in preliminary experimental test plots.

Fig. 1. Vineyard Street Nursery. View along the lower terrace, showing seedling trees growing in the partial shade of trees planted out in the ground. On the extreme right may be seen the trunk of a Charcoal tree, *Trema orientalis*, which is six years old. It is twenty inches in diameter three feet from the ground. Photo by E. L. Caum.

5. There was a direct correlation between temperature and cane growth; with a decrease in temperature there was a decrease in cane growth, and with an increase in temperature there was an increase in cane growth.

6. There was also a direct correlation between rainfall and eye spot counts; with every sudden increase in eye spot counts there was a corresponding increase in rainfall slightly preceding the increase in the eye spot counts.

Ten Years in Hawaiian Forestry

By H. L. Lyon

The department of botany and forestry of the Experiment Station, H. S. P. A., was established in 1918, and has now existed through a period of ten years. The work of this department has been recorded in monthly and annual reports, while special reports on the separate projects under way have been issued from time to time. An exhaustive report, reciting all the details of the numerous projects, propositions and negotiations which have engaged the attention of the department during the past ten years would, therefore, be but needless repetition of facts already on record. There are, however, matters pertaining to the organization and equipment of the department, and to certain phases of its activities, which have not been adequately recorded in any previous report. There are also cumulative results not apparent from day to day, or even from year to year, but which are quite evident when one scans a ten-year period. To complete the records of the department and otherwise round out its history is our excuse for preparing the present report.

When we began to study the local forestry problems and lay out a program for the department of botany and forestry we realized that our efforts along certain lines might easily be misconstrued, and provoke a merited opposition which would at once defeat our aims; for we were about to invade a field of work already wholly under the control of a government bureau, the Board of Commissioners of Agriculture and Forestry, which employed a forestry staff. Consequently from the very beginning we have tried, as representatives of the H. S. P. A., to maintain at all times the attitude of interested citizens and taxpayers, and not to exceed in any way the privileges of such in extending the scope of our departmental activities. We have undertaken extensive investigations and experiments in forestry, we have offered suggestions and assistance to the officers of the bureau, and we have argued the cause of forestry in public meetings and in the press, but we have carefully avoided any word or act that might be construed as an effort on our part to dictate or execute a Territorial forestry policy.

When we first entered forestry work the Territorial Forester was greatly handicapped by lack of competent assistants and dearth of funds for carrying on his work. At the outset it was evident that we could do much for the cause of

Fig. 2. *Ficus variegata,* a fig from Java. The specimen here pictured is growing in the Vineyard Street nursery. It was five years old when photographed. This tree is deciduous and remains leafless for a short period each year.

Fig. 3. *Ficus variegata.* Trunk of the specimen shown in Fig. 2 as seen close up. The figs are produced in abundance on short branches emanating from leafless portions of the trunk and larger branches.

Hawaiian forestry by assisting the Forester in his field work, and this has been our constant endeavor. In all matters pertaining to the administration of forest reserves, we have at all times subordinated our personnel to the Territorial Forester. This relation has been officially sanctioned by the Board of Agriculture and Forestry, which has commissioned each of our men an honorary forestry officer. On Hawaii and Kauai the administration of all government forestry projects has in recent years been placed in the hands of men drawn from our department, who now hold salaried positions on the staff of the Territorial Forester. We believe that an examination of forestry operations in Hawaii during the past ten years will show such complete accord between our department and that of the Board of Commissioners of Agriculture and Forestry as may be cited as an example of real cooperation.

The Reforestation Problem as We Found It

It has been recognized by all students of the Hawaiian flora that the indigenous trees and shrubs which constitute the rain forests on our watersheds are in a very delicate state of health, and that the slightest interference from man or his domestic animals so disturbs their balance that a rapid deterioration sets in which soon terminates in the death of the majority of the native plants. Certain pernicious shrubs, weeds and grasses which have been introduced into these islands, intentionally or inadvertently by man, find local conditions well suited to their requirements. They spread rapidly and always stand ready to occupy immediately any area vacated by the native plants. As a consequence, we see the native forests rapidly disappearing from our watersheds and their places being taken by open grass land or weedy scrub. The nucleus of the forces which brought about the destruction of the native forests and their replacement by foreign plants was introduced into this environment over a hundred years ago with the introduction of the white man's favorite domestic animals, the cow and the horse. These forces grew rapidly through multiplication and additions of their kind, while new forces of a deleterious nature were added with increasing frequency until there was soon arrayed against the native forests an irresistible strength before which they retreated with ever increasing rapidity. The speed with which a native forest would die out as a result of invasion by stock soon attracted the attention of naturalists, and as early as 1856 an anonymous author called public attention to this fact and its ultimate result in a paper published in a local magazine. It was many years later, however, before the Hawaiian government actually recognized the need of a forest conservation policy and called upon competent men to study the local forests and devise means of rehabilitating them.

The first attempts at reforestation in Hawaii were very naturally made with native trees. Repeated trials demonstrated, however, that the Ohia tree, which is the main constituent of all Hawaiian forests, would not lend itself to artificial propagation, and in fact could not be used successfully in reforestation. The Koa tree could be grown on limited areas only, but experience soon demonstrated that planted Koa trees were as a rule short lived. The foresters were eventually forced to the conclusion that the only means of reforesting our watersheds would

Fig. 4. Vineyard Street Nursery. View across the second terrace, showing at the left the trunk of a Yokewood tree, *Catalpa longissima*. In eight years this tree has attained a height of sixty-five feet. Photo by E. L. Caum.

be to employ exotics. The marvelous success obtained with such trees as Eucalyptus, Ironwood, Wattles, Monterey Cypress and Silver Oak proved conclusively that there were foreign trees which would grow and produce a forest cover in the very soils where the native trees failed to flourish. The results obtained in forest building with the trees named above, however, soon showed that these particular trees, in pure cultures of each variety or in mixed groves, would not produce an ideal water-conserving forest cover such as we desired to create on our watersheds, and it was obvious that other exotic trees of a more serviceable nature were urgently needed. Hawaiian forestry had just reached this stage in its development ten years ago when we were called upon to organize a forestry department to cooperate with the officers of the Board of Agriculture and Forestry in the solving of Hawaii's forest problems.

Upon analyzing the local forestry problems as best we could from the available evidence, we found that in addition to attacking some of these under the supervision of the Board of Agriculture and Forestry, our department could contribute much towards the solution of others by concentrating its attention upon the introduction of new trees and shrubs from foreign countries, testing these out under local conditions, and propagating those which proved most suitable for inclusion in the new forests which we must build on our watersheds. This was a strictly botanical undertaking which could be successfully executed by trained botanists only, and as the Board of Agriculture and Forestry had none such on their staff, it seemed quite appropriate that our department should take the initiative in this particular phase of forestry work and make it one of its chief endeavors.

When considering foreign trees for use in Hawaiian forestry, we realized that there already existed in this Territory a very large exotic flora which had resulted from the efforts of innumerable plant lovers who, in times past, had spent much effort and money in introducing plants to beautify their gardens. There were no records available whereby we could learn to what extent, if any, these plants had been tested out locally for forestry purposes, and it seemed certain that much valuable evidence and some valuable material could very soon be obtained if we tried out all exotics present in the Territory, along with such new ones as we were able to introduce. From those already present we could at once secure an abundance of seed and thus provide ourselves with ample material for immediate experimentation. The results obtained with some of the foreign trees already established in the Territory, but entirely neglected as possible components of the forests which we wished to build, have more than justified the efforts devoted to trees of this nature. At the present time it looks as though several of the trees best suited for planting on our watersheds are species of which specimens have been present in this Territory for many years, but whose potentialities were not recognized because they had not been tested out for forestry purposes. Trees of this nature will receive special mention in a later paragraph of the present report.

Vineyard Street Nursery

In order to engage in the growing and testing of exotic trees for forestry purposes, the first requisite of our department was an appropriate nursery in which

Fig. 5. Manoa Arboretum. The upper lands of Haukulu assigned to the arboretum include only sharp ridges with very steep slopes which lean up against the Manoa cliffs.

to plant the seeds of the various trees to be tested, and to rear the young seedlings up to an appropriate size for planting out in the field. Our interest in plant life had gained for us favorable consideration from Mrs. Mary E. Foster, who had acquired the garden founded by Dr. Hillebrand and, during her thirty years of possession, had not only preserved it carefully but had added adjoining land and embellished it throughout with many new plants. Learning that I was seeking an appropriate site for a nursery, Mrs. Foster very kindly offered for the purpose a very desirable piece of land adjoining her garden. It was in the center of a block, but she arranged to include with it two other pieces of property which gave us an entrance on Vineyard street, and a total area of 1.95 acres. We took possession under a personal agreement between Mrs. Foster and myself, but at a later date this was converted, with some modifications, into a formal lease by Mrs. Foster to the H. S. P. A. This first lease was for a period of ten years from the first day of January, 1919. In 1927 a new lease was obtained, including an additional piece of property, bringing the total area up to 2.522 acres. The second lease was for a period of twelve years from September 1, 1927. There were certain stipulations in the original agreement which do not appear in the leases. Some of these pertain to operations on the leased land, and others to work to be done in the old garden. Those pertaining to the leased land have been and are being carried out to the last detail, but a change in the management of Mrs. Foster's garden has made it impossible for us to execute all of the tasks which we were prepared to undertake to preserve and improve the older garden. The nursery site lies just makai of Mrs. Foster's garden, joining the same along a boundary of 304 feet. In times past it had been used as a vegetable garden, but when we took it over it had not been cultivated for some twenty years or more. This land carried one large clump of edible bamboo and a few sizeable trees, but was otherwise covered throughout with one solid thicket of Haole Koa and other weedy leguminous shrubs. It lay on a gentle slope, the mauka edge being some ten feet higher than the makai boundary. We agreed that while developing this as a nursery we would plant it up with new trees and shrubs in so far as it was possible to do so and not interfere with the area available for our work, or render it unsuitable for nursery purposes. The lower portion of Mrs. Foster's old garden is terraced, and in laying out the nursery we first terraced it in a manner corresponding with that obtaining in the garden above. We have also set out in the ground numerous trees and shrubs, until at the present time one portion of the nursery is a veritable forest. These trees occupy little ground space, however, and they afford the partial shade in which young seedlings grow to best advantage. Successful nursery practice requires that we keep a certain portion of our space quite open so that we can bring our seedlings out into full sunlight and harden them off before they are sent out for planting in the field. Most tree seedlings thrive best in their early stages if grown in partial shade, but such seedlings should be gradually brought out into full sunlight, for a quick transfer from constant shade to full exposure often results in the death of the seedling. We have endeavored to so plant up our nursery as to provide ideal conditions for handling seedlings and getting them into proper condition for transfer to the open ground

Fig. 6. Manoa Arboretum. A view up Aihualama valley with Haukulu on the left and Aihualama on the right. The brink of the pali in the background is the boundary between these lands and Kaakaukukui. A trail up the pali in Aihualama reaches Pauoa Flats or Kapukaawapuhi at about the center of the picture.

in various parts of these islands. The trees planted in the nursery have not only fulfilled our agreement with Mrs. Foster and supplied the necessary shade, but have also been an important source of seed supply. Naturally we selected some of the rarest and most valuable trees for planting in this situation, as here we could give them the most constant attention. Then too, the nursery site, protected on the mauka side by the big trees in Mrs. Foster's garden, affords veritable hothouse conditions, and consequently plants grow there as they would grow nowhere else on the island. Among the trees of note is a rare *Cassia* from Siam, and another from Central America. A Yokewood from Jamaica has attained a height of sixty-five feet in eight years, and has supplied us with an abundance of seed since it was one year old. It is the parent of a rapidly increasing and widely distributed progeny. A Chaulmoogra from Siam was the first tree of its kind to produce fruit in Hawaii, and its seedlings are already being distributed. The only clump of giant bamboo in the city occupies a central position in the nursery. It was grown from seed obtained in Ceylon. It is rapidly attaining such dimensions that it will be necessary to dig it out, and we expect to obtain from this one clump sufficient planting material to start some fifty plants in other situations. A specimen of the Charcoal tree from India has in six years' time attained the height of fifty-eight feet, with a trunk twenty inches in diameter three feet from the ground. A *Caesalpinia,* grown from seed obtained from Brazil in 1920, has reached a height of forty-five feet, a spread of sixty feet, and has a trunk twenty-five inches in diameter three feet from the ground. The only specimen of the Spanish Cedar in the Territory which has reached flowering size is located in the nursery. This tree yields a scented wood used in Cuba for the manufacture of cigar boxes. The two specimens of the Buttercup tree in the nursery supply all the seed we require for the propagation of this useful and ornamental tree. A tree of *Baryxylum africanum,* near the center of the nursery, is the only fruiting specimen of its kind in the Territory.

When we conducted our first negotiations with Mrs. Foster, looking towards the location of the nursery on her property, one of the conditions mutually agreed upon provided that we should at all times have access to her garden and be privileged to collect therefrom seeds of any or all of the rare trees growing therein. This privilege has been of great value to us as we have secured from her garden seeds of several trees which have proven of much importance in our forestry work. Among these the Queensland Kauri pine should receive special mention, for from the single magnificent specimen in her garden, we have secured the seed from which we have grown innumerable seedlings of this remarkable timber tree and distributed them to all parts of these islands.

In organizing and equipping our forest nursery in Honolulu we proceeded on the assumption that we would be permitted to ship young seedling trees in the boxes of soil in which they had been grown, to any of the other islands. This procedure was being followed at the nursery of the Board of Agriculture and Forestry. Before the seedlings from our first sowings had reached suitable size for shipment, however, the Board of Agriculture and Forestry enacted a new rule forbidding the shipment of plants in soil from Oahu to the other islands. This

Fig. 7. Manoa Arboretum. Upper portion of Aihualama as seen from Haukulu. This picture and that reproduced as Fig. 8 were taken at the same time and from the same setting, the camera being swung on the tripod between exposures. The high peak in the background is Kaumuhonu, which constitutes the mauka corner of the arboretum. Photos by E. L. Caum.

rule stopped shipments from their own nursery as well as from all other nurseries on Oahu. It was deemed necessary in order to prevent the transfer to other islands of a troublesome soil-dwelling insect that had become established on Oahu. This sudden and unexpected ruling of the Board seemed destined for a time to prevent the functioning of our nursery as a source for the general distribution of tree seedlings, but we soon devised a method of shipping the young trees in wet sphagnum moss, which proved quite as satisfactory as sending them forward in soil. To accomplish this successfully, however, we had to grow our seedlings to a much larger size, and this required that they be transplanted at least once in the nursery before being shipped. This increased many times the nursery cost of growing seedlings, and at the same time reduced in like proportion our chance of recording big shipments from our nursery. When seedlings are sent out in the flats in which the seed was sown, it is often possible to ship one box 4″x13″x18″ and truthfully record that you have shipped from your nursery a thousand or more seedlings. In order to get the seedlings from such a flat into suitable size for shipment from our nursery, we have to transplant them into at least fifteen flats of the same size, and hold them therein for from three to six months, during which time there will be some, and perhaps numerous, casualties. When we prepare these seedlings for shipment, the soil is washed from their roots, and they are done up in bundles of a given number, with their roots embedded in wet moss. A thousand seedlings so prepared for shipment occupy considerable space, the actual space required, of course, depending upon the size to which the seedlings have been grown, and the character of their foliage. Seedlings grown to a proper size for planting out before they leave the nursery and then shipped in moss, always receive prompt attention at their destination, and the number which actually get into the ground is nearly, or quite, 100 per cent of those leaving the nursery. When small seedlings are sent out from the nursery in the original seed boxes, the casualties among them are, as a rule, exceedingly heavy before they reach the open ground, so that of the thousands leaving the nursery, a very small percentage survive. Results obtained in the past ten years clearly prove that the most satisfactory and the most profitable results can be obtained by growing our seedling trees to a good size in the nursery before they are sent out. This plays havoc with a nursery record of trees issued, but at the same time it renders the records of some value as an index to the number of trees which are actually planted out in the ground. The method of shipping trees to the other islands, which we have been forced to adopt, has proven not only efficacious but economical, for we so pack our trees that they can be shipped to any destination by parcel post at small expense. Should the rule forbidding the shipment of plants in soil be rescinded, we would still ship most of our trees in moss.

During the past ten years we have distributed from the Vineyard Street nursery over 1,250,000 plants.

Manoa Arboretum

It is obvious that we cannot correctly estimate the extent to which any tree can be employed in our forestry work until we have tested that tree out under the range of temperature, moisture and soil conditions afforded at various elevations

Fig. 8. Manoa Arboretum. A planted slope in the lower portion of Aihualama as seen from Hau kulu. The trees are planted in rows cut through the heavy growth of Para grass. Stakes bearing the numbers of the rows may be seen along the trail which runs up the valley at the bottom of the planted ridge.

and in various parts of these islands. This would require that we undertake planting operations in several or many localities on each island of the group. The organization of our forest reserves was in such a state ten years ago, however, that it was quite evidently impracticable to at once lay out a large number of test gardens or arboreta in many localities. Seeds of foreign plants are usually obtained through correspondence with botanical gardens, botanists and collectors in other parts of the world. As a rule, seeds of desired plants are secured in small quantities only, and after these have passed through the vicissitudes of travel and one or more fumigations, they yield in most cases a very small stock of healthy seedlings. Many times we have obtained but one or two seedlings of some very desirable species of plant, the obtaining of the seeds of which had cost us much effort and time, and in some cases a considerable amount of money. In organizing and equipping the department of botany and forestry it was evident therefore that while a nursery was our first requisite, a second requisite of equal importance was a test garden or arboretum situated on a tract of land under the direct control of the Experiment Station, where we could test out all species of trees under consideration and where we could plant and care for the few specimens of rare plants reared from some of our seed introductions. Such a garden, to be most valuable, should be so situated that it would afford conditions of soil and climate approximating those obtaining on parts, at least, of the watersheds to be reforested. In addition to supplying trial grounds for our exotic plants, such a garden would in time be a source from which we could obtain seeds of those new plants which proved of promise, for the further distribution of the species on these islands.

Our plea for an arboretum received favorable consideration at once, and we began to cast about for a suitable piece of land for the purpose. When the Experiment Station acquired the Harrison property in the land of Haukulu, in upper Manoa Valley, during the early months of 1919, it was understood that not more than thirty acres would be devoted to sugar cane culture, while the rest of the area, some ninety-four acres, would be available to the department of botany and forestry for an arboretum. When we examined this property, however, it became evident that when the agriculturists had taken their thirty acres for cane culture, there would be left only pali land; sharp ridges with very steep slopes, which leaned up against sheer cliffs. These ridges were in reality talus slopes formed from debris which in times past had avalanched down from the cliffs above. A considerable part of the area allotted to us was already covered with native forests of complex composition, but with such trees as Koa, Kukui, and Lama predominating. While this land would afford us some room for tree planting, it was quite evidently inadequate for handling the problem confronting us, and so we began at once to seek an additional area. The land of Aihualama joined the newly acquired property of the H. S. P. A. throughout the length of Aihualama stream. Aihualama was owned in nearly equal parts by the B. P. Bishop Estate and Governor George R. Carter; the Bishop Estate land lying next to that of the H. S. P. A. A lease on the Bishop Estate land had recently expired and the trustees of that Estate desired to protect and develop this area as forest reserve as it was quite evidently an integral part of a watershed which was contributing to Honolulu's water

supply. It was obvious that in developing an arboretum on this land we would be improving it as part of the forested watershed, and negotiations with the trustees of the Bishop Estate soon secured for us a lease on this property for a thirty-year period from the first day of July, 1920, the H. S. P. A. contracting to pay rent of $1.00 on demand for the whole of said term. Covenants in this lease prescribing the uses to which we might and must put this property read as follows:

> That he will use the demised premises only for the purpose of a forest reserve as part of the acclimatization garden and forest nursery of the Manoa Substation of the Experiment Station, Hawaiian Sugar Planters' Association, and maintain and utilize the same as an arboretum during the whole term;
>
> That he will reforest that portion of the demised premises which is not adequately covered at the present time by forest (approximately 34.75 acres) with native and introduced trees and plants, properly spaced according to species, at the rate of not less than four (4) acres per annum.

Governor George R. Carter, the owner of the other half of Aihualama, became much interested in our undertaking to develop an arboretum on the Bishop Estate property adjoining his land, and in August, 1921, gave us a lease on his property to run for thirty years from the 23rd day of August, 1921. The terms of this lease were practically identical with those of the lease secured from the Bishop Estate, the stipulated rent being of exactly the same amount, to be paid under the same conditions. Governor Carter's property already carried a large grove of flourishing exotic trees which he had planted at considerable expense. The majority of the trees in this grove are Swamp Mahogany, *Eucalyptus robusta*, but it also contains several other species of Eucalyptus, the most notable of which is the Lemon Gum, *Eucalyptus citriodora*. Mahogany, Ironwoods, Tsugi, Wattles and Norfolk Island Pines are also present, and there are two fine fruiting specimens of the Turpentine tree, *Syncarpia laurifolia*. A single pine tree of undetermined species is making a successful struggle for existence. There are also several fine clumps of bamboo on the premises, in which at least three distinct species are represented. There is a very comfortable mountain house located in the upper end of the grove of exotic trees, and in the lease Mr. Carter has reserved the privilege of occupying this house for short periods each year. A famous swimming pool is located in one of the secluded valleys on the Carter property. This pool is kept constantly filled with clear, cold water which is piped down from a spring in the cliffs at the head of the valley.

By securing a lease on the two pieces of property in Aihualama we added an area of 141.36 acres to our arboretum. This gave us entire control over a secluded alcove in one corner of Manoa Valley. Roughly speaking it was a sextant of a circle, centered on the reverse curve in the government Loop Road, with its mauka boundary defined by the brow of the pali which roughly follows the arc of a circle. A very good idea of the configuration of this alcove may be obtained from the accompanying map and the photographs reproduced herewith as Figs. 5 to 8 inclusive. As in the case of Haukulu, the major portion of Aihualama is pali land, and a considerable part of this was occupied by native forest when we assumed possession. There was, however, some fifty acres suitable for use as trial garden.

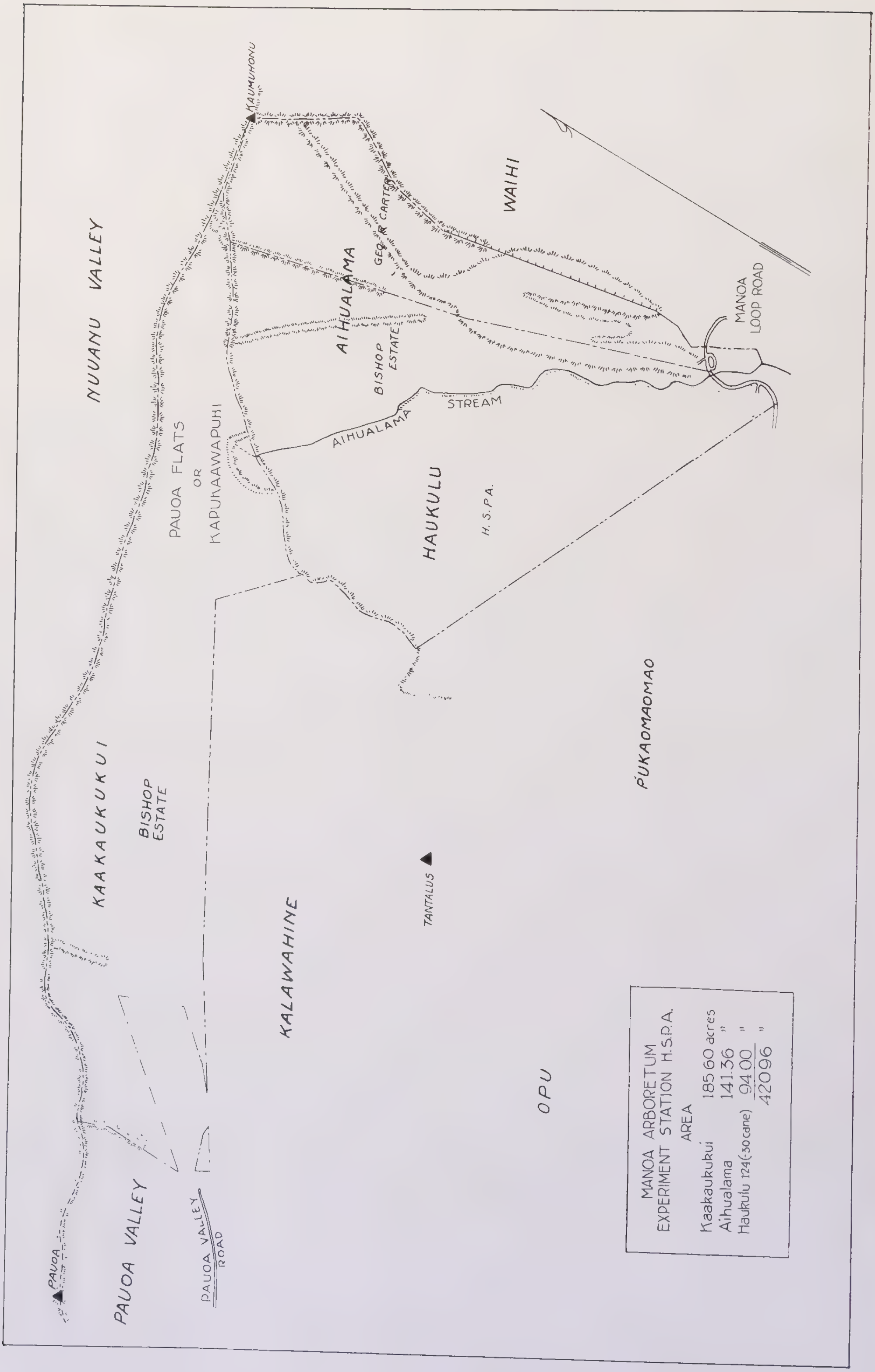
NUUANU VALLEY
KAUMUHONU
WAIHI
GEO. R. CARTER
AIHUALAMA
BISHOP ESTATE
MANOA LOOP ROAD
AIHUALAMA STREAM
PAUOA FLATS OR KAPUKAAWAPUHI
HAUKULU
H.S.P.A.
PUKAOMAOMAO
KAAKAUKUKUI
BISHOP ESTATE
TANTALUS
KALAWAHINE
OPU
PAUOA VALLEY
PAUOA
PAUOA VALLEY ROAD
MANOA ARBORETUM
EXPERIMENT STATION H.S.P.A.
AREA
Kaakaukukui 185.60 acres
Aihualama 141.36 "
Haukulu 124(30 cane) 94.00 "
420.96 "

Fig. 9. Manoa Arboretum. The Kaakaukukui section as seen from the air at about two thousand feet elevation. Pauoa Valley occupies the foreground at the right and Nuuanu at the left, with Pacific Heights ridge extending up the center of the picture. This ridge in its upper portion constitutes the ewa boundary of the arboretum lands which extend across the hanging valley onto the slopes of Tantalus ridge. The highest cultivated lands seen in the upper end of Pauoa Valley extend beyond the makai boundary of the arboretum. Kaumuhonu, the mauka corner of the arboretum, is the peak directly in line with, and below, Konahuanui. This picture was taken by the Air Ser vice of the U. S. Army, which has supplied us with a series of excellent photographs affording an unbroken panorama of both sides of the Koolau range.

This was in most part covered with Guava, Uluhi, Para Grass and Hilo Grass. Most of the land available for planting lay between the elevations of 400 and 1000 feet above sea level. There were a few small areas on pali slopes in which we might plant trees, thus carrying our operations on a small scale to an elevation of 1500 feet. While this property afforded us ample area for our immediate needs, it did not provide lands at high elevations, which seemed an essential requisite for proper experimentation along the lines which we should follow.

During our negotiations with the trustees of the B. P. Bishop Estate for the property in Aihualama, we learned that the Estate owned the land of Kaakaukukui, which joined Aihualama and Haukulu along the brink of the pali, and that the trustees were desirous of protecting and improving this land also as a part of Honolulu's forested watershed. As soon as we made known our needs for additional lands, they offered to lease to us all of their holdings in Kaakaukukui under terms identical to those in the lease of Aihualama, the lease to run concurrently with that of the last named property. A lease to Kaakaukukui was accordingly consummated, to run from the first day of January, 1924, for the term of twenty-six years and six months thence next ensuing.

The acquisition of Kaakaukukui added to our arboretum a total area of 185.6 acres. We estimated that in this land there was at least seventy acres from which the native forests had entirely disappeared, and this area was, of course, immediately available for arboretum purposes. Most of this denuded area lay between 1500 and 2000 feet elevation, and consequently afforded conditions of soil and climate absolutely essential for our purposes, but not to be found in Aihualama or Haukulu. Kaakaukukui takes in all of Pauoa Flats, and the better part of upper Pauoa Valley. Its ewa boundary runs along the crest of the ridge overlooking Nuuanu Valley. Its waikiki boundary starts from the highest point of Kaumuhonu and extends along the brink of the Manoa pali throughout the entire extent of Aihualama and half the mauka boundary of Haukulu. It then swings across the mauka slopes of Kalawahine and proceeds down the Pauoa slope of Tantalus ridge until it reaches the vegetable gardens of Pauoa Valley. The Pauoa Valley road extends to within a stone's throw of the makai boundary of this land. The shape and size of Kaakaukukui and its geographical relation to Haukulu and Aihualama may be seen by referring to our map. Kaakaukukui added many desirable features to the arboretum besides supplying us with the much needed land at high elevations for planting. Its strikingly irregular topography includes some most charming landscapes; brooks, streams, waterfalls, steep palis and sloping ridges arranged in picturesque combinations. It also carries extensive growths of native trees and plants in which are to be found numerous fine, healthy specimens of some rare and interesting species. We are striving to protect these remnants of a vanishing flora with judiciously placed barriers, and hope by so doing to preserve them as attractive features of our arboretum.

Pauoa Flats, or Kapukaawapuhi, affords a most interesting, and from our standpoint, most important physiographical feature. It is a hanging valley bounded on the Nuuanu side by a high, sharp ridge, and on the Manoa side by the opposed spurs of Kaumuhonu and Kalawahine, which are separated by a large

Fig. 10. Manoa Arboretum. Looking across Pauoa Flats towards the ridge above Nuuanu Valley. Kapukaawapuhi in the foreground is a bog covered with Hilo grass and bordered with guava bushes. Most of the native vegetation on the ridge in the background is dying or already dead.

and deep semicircular amphitheater cut into the crest of the Manoa pali. Kapukaawapuhi is the bottom of a diminutive water-catchment basin which drains via the amphitheater into Aihualama stream. Waters gathered in the amphitheater drop over the pali into Manoa Valley and, as Aihualama stream, flow through the lower section of the arboretum, constituting the boundary between Aihualama and Haukulu. This combination affords ideal conditions for the study of the influence of forest cover upon the run-off, and we shall observe with great interest any changes that take place in the Aihualama stream as a result of the reforestation of the catchment basin in which it takes its source. The topography of the Kapukaawapuhi basin and the condition of the vegetation which it carries is very well depicted by the photographs reproduced herewith as Figs. 9 to 12 inclusive.

In laying out and planting our arboretum to accomplish the purposes for which it was intended, it was necessary that all specimens planted be so located that their exact position could be recorded. The topography of the country in the arboretum was such that we could not lay it out in conventional geometrical figures bounded by roads and walks. The system adopted was the simplest and cheapest that we could devise. We first put in trails along the lines most easily traversed and then planted our trees in approximately parallel rows, at right angles to the general direction of a trail, each row continuing out from the trail until it reached some natural barrier, such as a gulch, the crest of a ridge, or existing forest. The main trails are divided up into numbered sections, the rows along each section are numbered and the trees are in turn numbered in the rows so that it is possible to keep a record of the exact position of each tree. In preparing the land for planting we have done no general clearing, but simply cut a wide swath through the guava bushes or uluhi fern along the line where a row of trees is to be planted. On the low and flatter lands we have, as a rule, spaced our rows approximately fifteen feet apart, and spaced the trees in the rows an equal distance apart. On steep slopes where the trees in one row will eventually overhang those in the row below, we have placed our rows much farther apart, the distance employed being determined by the slope of the land and the nature of the trees to be planted. We realized at the start that a spacing of fifteen feet apart each way would eventually bring our trees too close together if they all matured, but we also realized that many of the trees planted would undoubtedly fail to grow under the existing conditions, and that those which did survive and flourish would probably be provided ample space for their development through the death of some of their next door neighbors. In some cases we planted ten or more specimens of each species in a group with the intention of eliminating the poorer specimens when they began to interfere with each other. From the results obtained under our different methods of planting, we now aim to plant the different species in groups of ten to fifteen specimens whenever sufficient material is available to permit of this procedure. In mixed plantings it sometimes happens that several trees in close proximity to each other will flourish and that each one will prove to be the only surviving specimen of its kind in the arboretum. Under such conditions it is impossible to sacrifice any one of them when they begin to interfere with each

Fig. 11. Manoa Arboretum. Looking across Kapukaawapuhi from the rear slopes of Tantalus. The vegetation in the hanging valley is mostly guava bushes and Hilo grass, while some native vegetation still remains on the ridge above Nuuanu Valley.

other. We now strive to exercise great care in placing any single specimen of a rare tree that we secure.

At the present time most of the available land in Haukulu and Aihualama has been planted up. Shortly after securing Kapukaawapuhi we constructed a good trail on a moderate grade up the pali of Aihualama, emerging onto Kapukaawapuhi on the Konahuanui side of the amphitheater. Over this trail we have transported our material and made extensive plantings in a variety of habitats, including swamps, meadows, valleys, sloping hillsides and sharp ridges. Some of these plantings are in protected spots while others are fully exposed to the heavy winds which blow almost constantly across the flats from Nuuanu into Manoa Valley.

The building of effective water-conserving forests on our watersheds cannot be achieved by simply planting thereon groves of any tree that will thrive. This is fully demonstrated by the numerous planted groves of Eucalyptus to be found at various elevations on our mountain slopes. Obviously such groves do not fulfill the requirements, for what is needed are plant societies, including trees, shrubs, vines, herbs, ferns and mosses, which together form a water-conserving blanket of vegetation. Merely planting trees that will grow does not create such a plant society, or assure the segregation of appropriate plants into such a society. Just how the desired results can be accomplished through our efforts can be determined only through experiments. The Manoa arboretum is a field laboratory in which we are conducting such experiments. It not only affords us opportunities to test out plants of all descriptions under a variety of conditions, but also enables us to experiment with these plants in building plant societies.

From experiments in the Manoa arboretum we have already obtained results from which we can draw definite conclusions, and on which we can base definite recommendations. Up to the present time we have planted out in this arboretum one or more specimens of some nine hundred species of trees and shrubs. In the following list we name only those species, specimens of which have been in the ground four years or more, and have grown in such a way, and to such an extent, that we may safely conclude that they will continue to thrive and eventually reach maturity. The species showing the greatest promise are indicated by printing their names in bold-faced type. An asterisk in front of a name indicates that the plants of this species were reared from seed or cuttings of exotics already established in the Territory, while a dagger indicates that they were grown from seed obtained from abroad through the efforts of the department of botany and forestry.

† *Aberia gardneri*—Ceylon.
* *Acacia catechu*—East Indies.
† **Acacia confusa**—Philippines and Formosa.
† *Acacia robusta*—South Africa.
† **Acacia sp. No. 1338**—Fiji.
† **Acronychia laurifolia**—Tropical Asia.
* *Agathis robusta*—Australia.
† *Albizzia minahassae*—Celebes.
† **Albizzia moluccana**—Molucca Islands.
* *Albizzia procera*—Tropical Asia and Australia.
* **Albizzia stipulata**—East Indies.
* *Albizzia sp.*—Tropical Asia.

Fig. 12. Manoa Arboretum. Looking up Kaakaukukui towards the Nuuanu pali from the slopes behind Tantalus. The peak in the foreground on the right is Kaumuhonu, with Konahuanui directly behind it. The semicircular amphitheatre gouged in the crest of the Manoa pali occupies the center foreground of the picture. Aihualama stream takes its origin in this amphitheatre.

† **Alnus nepalensis**—Nepal.
† **Apeiba aspera**—Central America.
* **Araucaria bidwillii**—Australia.
* **Araucaria cunninghamii**—Australia.
* **Araucaria excelsa**—Norfolk Island.
* **Ardisia solanacea**—East Indies.
* *Artocarpus incisa*—Malaya and Pacific Islands.
† **Bambusa tulda**—Burma.
† *Barleria cristata*—Burma.
* *Barringtonia speciosa*—Polynesia.
* *Bauhinia variegata*—Southern Asia.
* *Bixa orellana*—South America.
* *Brassaia actinophylla*—Australia.
† *Brexia madagascariensis*—Madagascar.
† *Byrsonima crassifolia*—South America.
† *Caesalpinia melanocarpa*—Argentina.
† *Caesalpinia sp. No. 1299*—South America.
† *Callistemon citrina*—Australia.
† *Callistemon lanceolatus*—Australia.
* *Calophyllum inophyllum*—Polynesia.
* *Cananga odorata*—Malaya.
† *Canarium sp. No. 1474*—Malaya.
† *Cassia basilaris*—Tropical America.
† *Cassia moschata*—South America.
† **Cassia pilifera**—Brazil.
† **Cassia timorensis**—Timor.
† **Casuarina cunninghamiana**—Australia.
* *Casuarina quadrivalvis*—Australia.
† *Catalpa longissima*—West Indies.
† *Cecropia peltata*—Tropical America.
* **Cedrela australis**—Australia.
* **Ceiba pentandra**—West Indies.
† **Cerbera odollam**—Malaya.
† **Chamaecyparis lawsoniana**—United States.
† **Chrysobalanus icaco**—Tropical Africa.
* *Chrysophyllum cainito*—West Indies.
* *Cinnamomum camphora*—China and Japan.
* **Cinnamomum zeylanicum**—Malaya.
† *Cochlospermum hibiscoides*—Central America.
† *Cola acuminata*—Tropical Africa.
† *Combretum sp. No. 936*—Java.
† **Couthovia corynocarpa**—Fiji.
* **Cupressus pyramidalis**—Southern Europe.
* **Cupressus sempervirens**—Southern Europe.
† **Dillenia indica**—Tropical Asia.
† *Dillenia sp. No. 778*—Tropical Asia.
† *Diospyros mespiliformis*—Tropical Africa.
* **Dracaena marginata**—Madagascar.
* **Enterolobium cyclocarpum**—Brazil.
* **Eriobotrya japonica**—Japan and China.
* **Erythrina abyssinica**—North Africa.
* **Erythrina indica**—India.
† **Erythrina sp. No. 2300**—Central America.
† *Erythrophleum guineense*—Tropical Africa.
† *Eucalyptus alba*—Australia.

Fig. 13. Manoa Arboretum. A forest formation or plant society created in a valley in Haukulu by planting together numerous species of trees and shrubs. This planting was done in 1920 and the picture was taken in 1927. Photo by E. L. Caum.

* **Eucalyptus citriodora**—Australia.
* **Eucalyptus globulus**—Australia.
* **Eucalyptus robusta**—Australia.
* **Eucalyptus rostrata**—Australia.
† **Fagraea littoralis**—Java.
† *Fagraea obovata*—Malaya.
† **Ficus altissima**—India.
* **Ficus bengalensis**—India.
* **Ficus benjamina**—Malaya.
† **Ficus calophylloides**—Philippines.
† **Ficus ehretioides**—Australia.
† **Ficus eugenioides**—Australia.
† *Ficus forstenii*—Philippines.
† **Ficus glomerata**—India, Australia.
* **Ficus hispida**—Tropical Asia.
† *Ficus indica*—India.
* *Ficus infectoria*—Tropical Asia.
† *Ficus involucrata*—Java.
* **Ficus macrophylla**—Australia.
† **Ficus malunuensis**—Philippines.
† *Ficus nervosa*—Tropical Asia.
† **Ficus padifolia**—Mexico.
† **Ficus palawanensis**—Philippines.
† *Ficus polysyce*—Malaya.
† *Ficus pseudopalma*—Philippines.
* **Ficus retusa**—China, Malaya.
† *Ficus ribes*—India, Philippines, Java.
* *Ficus rumphii*—Malaya.
* *Ficus religiosa*—India.
† **Ficus stephanocarpa**—Australia.
† **Ficus sp. No. 876**—Malaya.
† **Ficus sp. No. 1272**—Siam.
† *Ficus sp. No. 1312*—Fiji.
† *Ficus sp. No. 1360*—Prince-of-Wales Island.
† *Ficus sp. No. 1466*—Philippines.
† *Ficus sp. No. 1486*—Siam.
† *Ficus sp. No. 1502*—Philippines.
† *Ficus sp. No. 1551*—Java.
* **Fraxinus sp. L246**— ?
† *Gonocaryum fusiforme*—Malaya.
† **Gourleia decorticans**—Chile.
† *Gynocardia odorata*—Burma.
† *Heliocarpus americanus*—Central America.
* *Heritiera littoralis*—Old world tropics.
† *Hernandia peltata*—Old world tropics.
† *Heterophragma adenophyllum*—East Indies.
* **Hibiscus elatus**—West Indies.
* *Hibiscus macrophyllus*—Malaya.
* *Hura crepitans*—South America.
† *Hydnocarpus anthelminticus*—Burma.
† **Ilex paraguayensis**—Paraguay.
* **Jacaranda ovalifolia**—Central America.
* *Jatropha curcas*—Tropics.
* **Juniperus australis**—Australia.
* **Juniperus bermudiana**—Bermuda.

Fig. 14. Manoa Arboretum. A very effective bit of rain forest on the Carter property created by planting ginger and a climbing aroid in a Kukui grove. This planting was done prior to our tenancy. A dense growth of ginger, with stems six to eight feet tall, covers the forest floor, while the trees hang full of the giant aroid. This combination is very pleasing to look upon, and at the same time constitutes a very efficient water-conserving plant society.

* *Kigelia africana*—South Africa.
† **Kydia calycina**—East Indies.
* *Lagerstroemia flos-reginae*—Tropical Asia.
† **Leptospermum gracilis**—Australia.
* *Lonchocarpus sericeus*—Tropical America.
* *Macadamia ternifolia*—Australia.
† **Macaranga grandifolia**—Philippines.
† **Macaranga tanarius**—Malaya.
† **Mallotus philippinensis**—Philippines.
* **Mammea americana**—Tropical America.
* **Melaleuca leucadendron**—Australia.
* *Melaleuca nesophila*—Australia.
* *Melochia indica*—India.
† *Melochia odorata*—Tanna.
† *Melochia sp. No. 1414*—Tropical Asia.
† *Mezzettia parviflora*—Borneo.
* **Michelia champaca**—Malaya.
* *Morus alba*—Asia.
† *Muntingia calabura*—West Indies.
† *Myroxylon sp. No. 2323*—Tropical America.
* *Nephelium litchi*—China.
† *Ochroma lagopus*—Tropical America.
* **Olea europaea**—Southern Europe.
† *Owenia cerasifera*—Australia.
† **Parkia africana**—Tropical Africa.
† **Parkia timoriana**—Timor.
* *Persea gratissima*—Tropical America.
* *Phyllanthus emblica*—Tropical Asia.
* *Pimenta officinalis*—West Indies.
† **Pithecolobium tortum**—Brazil.
† **Podocarpus cupressina**—Malaya.
† *Polyscias nodosa*—Malaya.
* *Pongamia mitis*—Nicobar.
* **Psidium cattleyanum lucidum**—Brazil.
* *Pterocarpus indicus*—Tropical Asia.
† *Pterocarpus marsupium*—East Indies.
† *Pterospermum sp. No. 1182*—Tropical Asia.
* **Ravenala madagascariensis**—Madagascar.
* **Rhus semialata sandwichensis**—Hawaii.
* *Rhus sp.*— ?
* **Sanchezia nobilis**—Ecuador.
* **Schizolobium excelsum**—Brazil.
† **Simaruba glauca**—Tropical America.
* *Spathodea campanulata*—South Africa.
* *Spondias lutea*—Tropics.
† *Sterculia alata*—East Indies.
† *Sterculia sp. No. 2267*—Tropical America.
* *Swietenia mahogani*—Tropical America.
* **Syncarpia laurifolia**—Australia.
* *Tectona grandis*—Tropical Asia.
† *Tecoma argentea*—Paraguay.
† *Terminalia arborea*—Java.
* **Terminalia arjuna**—East Indies.
† *Terminalia comintana*—East Indies.
† **Terminalia myriocarpa**—Burma.
† *Terminalia sp. No. 1696*—Tropical Asia.

† **Tetrazygia bicolor**—West Indies.
† **Thryalis braziliensis**—Brazil.
† **Trema orientalis**—Old world tropics.
* *Vitex pubescens*—Tropical Asia.
* *Vitex vestita*—Malaya.
† *Vitex sp. No. 1902*—Philippines.
† *Undetermined sp. No. 912*—Java.
† *Undetermined sp. No. 2243*—Central America.

Figs in Hawaiian Forestry

In our search among exotics for suitable trees to be used in the reforestation of Hawaiian watersheds, we early arrived at the conclusion that some species of the genus *Ficus* would not only be of great value in our forestry work, but might even prove a complete solution for some of our most serious problems. In a paper published in the *Planters' Record* for December, 1919, we presented our reasons for concentrating our attention on the genus *Ficus,* outlining the methods which we should follow, and indicating the results we might reasonably expect to obtain. In brief, we viewed the situation somewhat as follows: The genus *Ficus* includes over six hundred known species, and affords plant types ranging from tiny vines and shrubs to enormous trees attaining the greatest bulk to be found among existing plants. Trees of this genus occur throughout the tropics of the world, and constitute important elements in most rain forests, but the indigenous Hawaiian flora did not include a single species. Many figs show remarkable ability to grow and thrive under a great range of soil and climatic conditions. Figs are also noted for their ability to survive abuse and to recover after serious mechanical injury. Their great capacity for regenerating mutilated or amputated members may be taken advantage of by using slips or cuttings for propagating a species. As a matter of fact, this is the usual means by which ornamental figs are multiplied for commercial purposes.

In its native habitat, a fig tree produces enormous quantities of small seeds which are enclosed in fleshy pseudo-fruits or figs. These are usually sweet, thus making them an attractive food to such birds, bats and other animals as partake in part of a vegetable diet. A fig seed has a hard coat, and passes through the alimentary canal of an animal without having its vitality impaired. Living seeds are consequently deposited in all sorts of places by the birds and animals which have fed upon the fruits. Fig seedlings are by choice perching plants, and the majority of the fig trees in present day forests began their existence as seedlings perching on some other plant or the remains of some other plant, for they can start quite as well on an old stump or log as on the trunk or branch of a living tree. From such an elevated position a fig seedling throws its branches upward to form a crown, and sends its roots down to the ground to establish independent connections with the soil. These roots then thicken up and fuse together into a trunk which often surrounds and includes the object on which the seedling originally perched. Eventually a large tree develops, with a trunk capable of supporting the crown without the help of the host plant. In tropical forests it is often possible to determine that a big fig tree has developed from a seedling which perched on another tree at least a hundred feet above the forest floor.

Fig. 15. *Ficus altissima* in the Manoa Arboretum. The picture was taken when the tree had been in the ground five years and four months. This is one of the most promising of the many species of figs which we now have under trial. Photo by E. L. Caum.

Fig. 16. *Ficus altissima.* Trunk and aerial roots of the specimen pictured in Fig. 15 as they appeared when the tree was six years and four months old, showing by comparison the remarkable growth made in one year's time. Photo by E. L. Caum.

The unique role which the figs might play in Hawaiian forestry is very interesting to contemplate. There are on our watersheds extensive tracts still covered with dead and dying forests. This blanket of decrepit vegetation, with an invading undergrowth of Hilo grass and Uluhi, presents a serious obstacle to the planting of trees according to the usual methods followed in reforestation. This same vegetation, however, affords the precise conditions required for the natural spread of fig trees. If seed-bearing figs were prevalent in the vicinity of such a forest, and fruit-eating birds were present to eat the fruit and deposit the seed upon the dead and dying trees wherever they happened to perch, we might reasonably expect that fig trees would eventually become established throughout such a forest without any further help from the foresters. Perched upon a tree or log high above the forest floor, a fig seedling would in no way be disturbed by the Hilo grass and Uluhi, which would effectually smother all tree seedlings attempting to start up from the ground below.

To inaugurate a most desirable sequence of events it seemed only necessary therefore to infect our decadent forests at frequent intervals with seed-bearing fig trees. The mynah birds, which have an inherent taste for such food, would eat the figs and distribute the seed for us. We could not expect that the results obtained would be immediately noticeable, but we would have started a natural process of reforestation which would constantly gather headway as the number of fig trees multiplied. This proposition seemed so plausible and so certain of producing the desired results that we formulated a program which would serve to put it into active operation. When we took an inventory of the materials and forces which must be assembled we found that the project was already well advanced, but that we should have to supply a few very essential factors to make it effective.

An examination of our exotic flora showed that there were already present in Hawaii many mature specimens of figs, among which some twenty species were represented. The trees of several species were very evidently of a type that could be used to good advantage in our forestry work. Many of these fig trees were mature and flowered periodically or continuously; but every one of them failed to produce viable seeds. The reason for their delinquency in this respect was the absence of certain insects which carry the fig pollen from flower to flower and on which the plants rely for the execution of this important operation in their life cycle. In its native habitat, there is associated with each species of *Ficus,* a particular wasp which breeds within the figs, and in its endeavors to perpetuate its own species, conveys the pollen from the staminate flowers in one fig to the pistillate flowers in another, thus enabling the latter to set seed. Now, to render the local fig trees seed-producing, we should have to introduce their specific wasps. This seemed a simple matter, for we knew that our entomologists were accustomed to go even to the ends of the earth if need be, and bring back alive beneficial insects. We therefore selected from among the figs already present in Hawaii the species that seemed most suitable for forestry purposes, and then asked the entomologists to get the proper wasps for us. We realized that the task would require time, but we were confident that it would ultimately be accomplished.

Fig. 17. *Ficus bengalensis.* When this picture was taken the tree had been in the ground five years on an exposed Uluhi-covered ridge. This species can most certainly be used to good advantage in our forestry work. Photo by E. L. Caum.

Although there were several figs already represented by mature specimens here in Hawaii, these specimens were not located at strategic points on our watersheds. The first undertaking of our department in the active promotion of the fig project was to raise young plants and distribute them as widely as possible throughout the islands. Since the local trees did not produce seed, we had to import seed from abroad or rely on propagating the trees by means of slips or cuttings. In multiplying and distributing figs, we did not rely wholly on the species already present in Hawaii, but secured seed of as many species as possible, grew young plants of all of them and planted these out on our forest lands to determine which species grew best under our conditions, and produced trees most suitable for inclusion in our forests. It is perfectly safe for us to play with figs in this way, for none of them will spread naturally until we introduce their specific wasps, so if trees of any species show characters or habits which render them undesirable constituents of our forests, we simply neglect them, knowing that they will never spread. During the past ten years this department has secured seed of some eighty species of figs, grown young plants at the Vineyard Street nursery, and sent out seedlings for planting at many points for trial as to their suitability for forestry purposes. Those trees which survive in such situations may eventually become seed-producing and serve as a focus for the dissemination of their species if we introduce the necessary wasps to make them seed-bearing. In the Manoa arboretum there are now growing specimens of eighty-five species of *Ficus*. Most of these have been grown from seed, but a few were derived from cuttings from local trees and others from trees growing in foreign countries. The species which have proved most promising we have already indicated in the list printed on pages 76 to 83. For each of these species we should sooner or later secure the appropriate wasp to render our local specimens seed-producing. For species recently imported, this of course cannot be done until our local trees have reached fruiting size. A number of the species which we have been responsible for introducing into the islands are already represented by numerous fruiting specimens, and their wasps can now be imported, as they will find a constant supply of fruits in which to perpetuate their species.

When Mr. Pemberton went to Australia in 1920 his major project was to be the study of Australian figs and the wasps associated with them, with a view to introducing both into Hawaii and making them cooperative in our forestry work. He collected and forwarded to us large quantities of seed of numerous species of *Ficus* which he found growing in Queensland and New South Wales. From this seed we reared thousands of seedlings of each, and distributed them widely. Of two species, the Moreton Bay fig, *Ficus macrophylla,* and the Port Jackson fig, *Ficus rubiginosa,* we had found a few mature specimens here in Honolulu, and Mr. Pemberton soon undertook to send us the proper wasps for these. He gathered figs which were approaching maturity, and, placing them in containers of his own design, shipped them to Honolulu in cold storage. Shortly after these figs reached our laboratories, the wasps began to emerge and were liberated in the local fig trees, where they promptly established themselves. In a short time these trees began to produce quantities of figs containing viable seed, and from that time up

Fig. 18. *Ficus retusa* in the Manoa Arboretum. This, the well-known "Chinese banyan," seems to be one of the most promising trees for planting on our watersheds. This specimen had been in the ground five years and four months when the photograph was taken. Photo by E. L. Caum.

to the present, we have secured an abundant supply of local grown seed of these two species.

There is one large tree of *Ficus macrophylla* in Emma Square, and another in the old acclimatization garden on upper Nuuanu. These trees bear fruit the year round, but at certain seasons they drop an extra heavy crop during a period of three to four weeks. In 1922 we collected all the fruit we could get from one such crop dropped in a period of four weeks by the tree in the acclimatization garden. From this fruit we obtained 224 pounds of dry seed. We planted half an ounce of this seed, and from it secured 915 seedlings. At this rate our 224 pounds of seed, if all properly sown, would yield 6,558,720 seedlings. This one tree, in a single crop of fruit, produced enough seed, if it could be properly placed, to reforest all of the watersheds on these islands.

There is a single large tree of *Ficus rubiginosa* on the slopes of Tantalus above Makiki Heights. The wasps sent from Australia by Mr. Pemberton were liberated in this tree and established themselves there, causing the tree to produce viable seed. The fruits of *Ficus rubiginosa* are much smaller than those of *Ficus macrophylla* and the seeds are also smaller in about the same proportion. We have never made an attempt to estimate the seed produced in one crop by the specimen of the Port Jackson fig on Tantalus, but at times it must produce quite as many as does the Moreton Bay fig at the old acclimatization garden. A year or more after wasps had become established in the tree on Tantalus, Dr. Dean called our attention to a change which had taken place in the fruits produced by a fig tree on his premises in Manoa Valley. An examination of this tree showed that it was a Port Jackson fig, and that its fruits contained fully formed seed, as they were infested with wasps. These minute wasps had found their way to Dr. Dean's tree from the tree on Tantalus, over a mile away in a direct line. In migrating to this isolated tree in Manoa Valley they had to travel over the slopes of Round Top, making a considerable part of their journey against the trade winds. This seemed a remarkable feat for such tiny creatures, which appear to be very weak on the wing. However, in recent months we find that they have managed to travel unaided to such remote places as forests above Wahiawa and Laie, where there are now fruiting specimens of their host tree, developed from seedlings which we planted out six or eight years ago in these localities. The wasps of *Ficus macrophylla* are much larger than those of *Ficus rubiginosa* and appear to be stronger on the wing. They have also moved out unaided to other parts of the island, for just as fast as specimens of their host tree in our various plantings in the mountains reach fruiting size, the wasps appear on the scene to bring about the pollination of their flowers and render them seed-producing.

There is a third Australian fig, *Ficus glomerata,* in many of our forest plantings which is now producing an abundance of young fruits which never mature because the wasp of this fig has not yet been introduced. There were no specimens of this tree in the island when we undertook the fig project, all of our specimens having been grown from seed collected in Australia by Mr. Pemberton. When Mr. Pemberton left Honolulu a few months ago for Australia and New Guinea, he planned to ship this wasp from Queensland at the first opportunity

During his short stay in Queensland, however, he found no material in suitable condition for shipment, and consequently had to defer this operation until he returns to Australia from New Guinea. We are confident that he will succeed in introducing this wasp even as he did the other two.

There are a great many species of striking fig trees which range through India and the Malay Archipelago. Several of these, and particularly the Banyans and India rubber tree, are among the best known species of the genus *Ficus*, and are now widely distributed throughout the tropics of the world. These, and several other species of Oriental figs, were already represented in the exotic flora of Hawaii when we became interested in the genus, and some of these were included in our list of species for which wasps were desired. Hawaiian entomologists were making frequent visits and protracted stays in the Orient, and they gave this endeavor much careful attention. Dr. Williams, working in the Philippines, made several attempts to ship back insects to us, but the time consumed in the journey proved too long, the insects all emerging from the fruits and dying before their arrival in Honolulu. Mr. Fullaway shipped some figs containing insects from Hongkong. Most of the insects emerged and died during the journey, while the few which emerged after the fruits reached our laboratory were apparently too weak to function, for although we gave them every care and attention, they failed to establish their species in our trees. Of all the fig trees which we have tested out to date, the Chinese Banyan appears to be one of the very best for our purposes. Fruiting specimens of this Banyan are numerous in Hongkong and from this source we have tried to secure the proper wasp. All of our attempts up to the present time have failed, but we are now devising schemes whereby we believe we shall be able to bring these insects through alive. Their successful introduction is a matter of such importance to Hawaiian forestry that we believe we are justified in sending a specially equipped expedition to Hongkong to accomplish this errand.

During the past ten years we have had added to our exotic flora a great many species of Oriental figs. Through the painstaking efforts of Dr. Williams we received quantities of seed of many of the more important species of *Ficus* which ranged through the Philippine Islands. Specimens of some of these species have now reached fruiting size in our cultures, and will become seed-producing whenever we bring in their respective wasps.

If fig seeds will germinate and develop into trees when sown in elevated positions by birds, they should do the same if sown in similar positions by the hand of man. We therefore started experiments of throwing seed into such positions when traveling through the forests on foot. When retracing our footsteps in later months, we found thriving fig seedlings in positions where we had previously thrown seed. If this operation resulted in success, why would it not be possible to fly over our decadent forests in an airplane, dropping fig seed wherever favorable conditions seemed to exist for their reception. It is obvious of course that most of the seed so dropped would land in situations where it could not grow and thrive, but if one tree eventually matured for every hundred thousand seeds so sown, the results obtained would be worth the effort. From the statistical informa-

Fig. 19. *Ficus hispida* in Manoa Arboretum. Trees of this species do not attain great size, but they are extremely hardy, fruit heavily, and are said to spread rapidly in their native habitat. This specimen had been in the ground five years when the above picture was taken.

Fig. 20. *Ficus hispida* in Manoa Arboretum. Trunk of the specimen shown in Fig. 19 as it appeared two years later. Numerous leafless branches springing from the trunk bear figs in great numbers. Photo by E. L. Caum.

tion given above, it is evident that enormous numbers of fig seeds can be obtained at little expense. By using an airplane, a reasonable number of these seeds could be deposited where they would germinate and produce trees in situations practically impossible of approach in any other manner. The Air Service of the U. S. Army has shown great willingness to assist us in this endeavor, and already many sowings of seed have been made from Army airplanes on the forest reserves of Oahu. On one occasion, while on a visit to the island of Hawaii, several planes distributed seed over the Panaewa Forest Reserve which had been laid waste over a considerable area by a forest fire.

When in 1919 we wrote the paper previously alluded to, recommending the use of figs in our forestry work, we confidently stated that they would prove of great value to us. The experimental work which we have done with figs since that time has demonstrated that our confidence was in no way misplaced, for if we erred, it was in underestimating their value. We now have in our cultures a dozen or more species that grow luxuriantly on our watersheds and produce trees of an ideal type for inclusion in a rain forest. Some of these figs are superior in every way to any and all other trees in our cultures. We have demonstrated beyond a doubt that we can successfully build forests with fig trees as their major constituents.

We have learned many interesting and helpful facts regarding the culture and propagation of figs. Young seedlings of many species are rather difficult to handle in the nursery because they do not like to start out in life from the position in the soil where we are wont to plant the seeds. They prefer to spend their youth in some elevated and well aerated situation. After the seedlings have reached a height of two or three inches they can be readily handled according to ordinary nursery practice. Most of the figs can be propagated in the field by simply thrusting cuttings into the soil. Some species give much better results than others when handled in this manner. We have found that, as a rule, we could get more strikes from cuttings placed in the soil in the Manoa arboretum than we could obtain from similar cuttings placed in soil or sand in boxes at the Vineyard Street nursery. Good results have been secured from moderate sized cuttings which were simply thrust into the soil in Hilo-grass-covered areas. The resulting trees were able to come through without any cultivation, as they formed crowns well above the Hilo grass. Our laborers in the arboretum, upon discovering that cuttings of certain figs rooted freely, started a planting campaign of their own. As a result, we now have some fig trees in situations which were being reserved for other plants.

Our fig project has successfully passed the critical tests and we can proceed with its further elaboration with every assurance that we are laying the foundations for a natural and permanent rejuvenation of our forests. Specimens of many good species of fig are already widely distributed on our watersheds, but we should now undertake systematically to build orchards of the better species at frequent intervals in the borders of all our rain forests. Whenever a sufficient number of specimens of any good species reach maturity in our cultures, we should take the necessary steps to introduce the wasp belonging to that species,

Fig. 21. *Clusia rosea.* A "Scotch attorney" residing in Honolulu in the neighborhood of the Experiment Station. Photo by E. L. Caum.

and thus render our local trees seed-bearing. Several remarkable species of figs are already represented by such a number of mature specimens as would serve to maintain their wasps should these be introduced at this time. It is obvious therefore that the next step in the development of our fig project should be the introduction of fig wasps from abroad.

Another phase of the fig project which might well receive special attention is the introduction of additional fruit-eating birds to aid the mynah in the distribution of fig seeds in our forests. When returning from Panama last winter we were able to secure and bring back to Hawaii a few pair of three species of Central American game birds for release in our forests. In introducing these birds we were acting on written and cabled instructions from officers of the Board of Commissioners of Agriculture and Forestry. All of these birds are fruit-eaters and tree-dwellers, and if they become established in our forests, will prove far more efficacious than the mynah in distributing fig seed in the localities where we are particularly desirous of getting them placed. It would be a good policy to bring in more of these same birds as soon as possible so as to insure the establishment of their species in our forests.

Introducing the Scotch Attorney

During our stay in Cuba in 1920 we made the acquaintance of another tree with habits somewhat like those of the figs. We did not learn the Cuban name for it, but its scientific name is *Clusia rosea.* It has fan-shaped leaves four to eight inches broad which are rather fleshy and quite rigid. It produces large, handsome, rose-colored flowers, and attractive fruits two to three inches in diameter. Like those of the figs, the seedlings of *Clusia* prefer to start out in life in some elevated position. They may perch on a tree, but they seem equally satisfied to start on a stone wall or a bare rocky cliff. I found several seedlings one to two feet tall growing on a stone wall. They had numerous roots intertwined over the surface of the wall, but so far as I could find, none of these roots had as yet established connections with the soil. While in Cuba I collected a quantity of seed of this tree, but it failed to yield any seedlings when planted upon my return to Honolulu. After repeated attempts I finally succeeded in raising two seedlings from a small quantity of seed forwarded to me by Mr. Gray, of the Harvard Botanical Garden at Soledad, Cuba. These seedlings have now developed into sizeable trees but neither has as yet flowered. We have, however, succeeded in rooting numerous cuttings, by which means we have increased the population and distribution of this tree in Hawaii.

During our recent visit to Trinidad and British Guiana we met with the same and other species of *Clusia,* all displaying similar habits and characters to those mentioned above for *Clusia rosea.* In Trinidad they call a tree of this nature a "Scotch attorney." It merits this name, I was told, because "it always squeezes its client to death." In Trinidad, Clusias range from sea level to the tops of the mountains which reach 3000 feet in elevation. One species, *Clusia intertexta,* is the most conspicuous and abundant component of the flora on the summit of their

highest mountain, the Aripo, where it forms almost impenetrable jungle with its long straggling branches and intertwining aerial roots.

The Clusias are spread even as the figs are spread. They offer some advantages, however, over and above those presented by the figs, for in addition to starting on trees, logs, etc., they show a special inclination to start on open rocky land and exposed barren palis where they produce dense vegetation, which clings to the substratum with great tenacity. Then, the Clusias do not require the assistance of specific insects to bring about the pollination of their flowers.

The Filtration of Settlings

By H. F. Bomonti

In a previous report on the treatment of settlings and the Oliver Filter, published in the *Record,* Volume XXXI, No. 1, detailed data, showing the effect of various treatments on the filtration characteristics of settlings are given. The data in the above mentioned report were all taken from the tests made at the Oahu Sugar Company. For this reason the writer visited a number of factories, located on all the islands and in the various districts on each island, to determine the filtration characteristics of the settlings when subjected to the same chemical treatments.

Tests were made at eighteen factories, not including Oahu Sugar Co. They are as follows:

Oahu. Honolulu Plantation Co., Ewa Plantation Co., Waialua Agricultural Co., Kahuku Plantation Co.

Maui. Pioneer Mill Co., Wailuku Sugar Co., and Maui Agricultural Co.

Hawaii. Hawaiian Agricultural Co., Olaa Sugar Co., Waiakea Mill Co., Hilo Sugar Co., Laupahoehoe Sugar Co., Honokaa Sugar Co., Hawi Mill & Plantation Co.

Kauai. Makee Sugar Co., Lihue Plantation Co., Hawaiian Sugar Co., Kekaha Sugar Co.

The experimental filter unit and also the method of procedure in making these tests are fully described in the article already referred to. Filtration tests were made on the settlings as discharged from the settling tanks without preliminary treatment, after liming to 8.5 to 8.9 pH, and after acidifying the limed settlings with phosphoric acid to 6.8 pH. This latter treatment is known as the Borden process.

In view of the successful operation of the Oliver Filter at the Oahu Sugar Co., complete data were secured on the Borden treated settlings in order to determine the range of variability of the settlings that might be encountered in applying the filter to the industry generally. Samples were examined at the above factories in an effort to cover variations that might come from cane variety, climate, soil, flum-

ing, and factory equipment. At none of these plantations were enough samples taken to make the work representative of the condition of the settlings as it might vary throughout the season.

The composition of the suspended solids in settlings varies considerably during the year, and, perhaps, more so on the non-fluming plantations than on the fluming plantations. For this reason, all comments on the filtration characteristics of the settlings at any of the factories refer solely to the conditions which prevailed at the time of these visits.

The filtration data of the settlings for each factory have been tabulated and discussed in the following pages. The term "filtration rate" has been used in the text instead of the phrase "volume of filtrate" as given in the tables.

Filtration data of the settlings of Honolulu Plantation Company. Date of tests, April 18, 19, 20, 1927:

Untreated Settlings	Limed Settlings		Treated Settlings by the Borden Process					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
350 cc.	..	...	6.8	1025 cc.	235 gms.	1/4 "	35 secs.	3.5
500 "	..	...	6.8	1000 "	...	1/4 "	..	..
...	8.6	875 cc.	6.7	1050 "	240 "	1/4 "	40 "	3.5
775 "	8.6	1025 "	6.9	1275 "	125 "	3/32"	25 "	1.8
475 "	..	...	7.0	975 "	300 "	5/16"	40 "	4.7
600 "	8.7	1000 "	6.8	1325 "	115 "	3/32"	25 "	1.6
400 "	..	...	6.8	1600 "	280 "	5/16"	35 "	3.0
300 "	8.6	600 "	6.8	800 "	300 "	5/16"	30 "	5.5
400 "	..	...	6.9	1450 "	365 "	3/8 "	25 "	4.0
Av. 475 cc.	8.6	875 cc.	6.8	1167 cc.	245 gms.	1/4 "	32 secs.	3.45

The filtration characteristics of the settlings at this factory are very similar to those found at the Oahu Sugar Company in their response to lime and phosphoric acid (Borden process). The relatively low initial filtration rate for untreated settlings is quite characteristic of the settlings at Waipahu. After liming to 8.6 pH there is an increase in filtration rate amounting to over 100 per cent. Further acidifying these limed settlings to 6.8 pH results in an increase of the filtration rate.

The cake formed during these tests averaged ¼", cracking in slightly over 30 seconds. This indicates that the cake was quite porous and should be easily sweetened off. Studying the data, it will be observed that there is quite a wide variation in the suspended solids in the settlings. These differences were due largely to the type of settling tanks in use at the time. With a Dorr clarifier (to be in use for the 1929 crop) it is quite likely that the per cent suspended solids in the settlings will be more uniform.

Filtration data of the settlings at Ewa Plantation Company. Date of tests, February 15, 16, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	8.4	800 cc.	6.8	1400 cc.	124 gms.	3/32″	60 secs.	1.6
...	8.7	800 "	7.1	1150 "	110 "	3/32″	45 "	1.7
...	9.0+	825 "	6.8	1150 "	140 "	1/8 ″	45 "	2.0
...	9.0+	950 "	6.8	1140 "	130 "	1/8 ″	45 "	2.0
900 cc.	8.8	1025 "	6.9	1350 "	145 "	1/8 ″	48 "	1.9
900 "	8.6	950 "	6.8	1375 "	140 "	1/8 ″	45 "	1.8
Av. 900 cc.	8.8	900 cc.	6.9	1260 cc.	131 gms.	1/8 ″	48 secs.	1.8

The per cent suspended solids of the settlings at this factory is very low, varying from 1.6 to 2.0 per cent. Although the tests showed a fair response to the phosphoric acid treatment, resulting in a filtration rate of 1260 cc., the cake which was formed was less than ⅛″ in thickness. The time of cracking was 48 seconds. This is high for such a thin cake, indicating that the cake is not very porous. The mill juices at Ewa are strained through a No. 00 screen having 625 perforations per square inch. This fine screen removes a large portion of the fiber or cush cush, which would be present in the juice provided coarser screens were used. The writer believes that it is a good practice to use fine mill screens, provided good results can be secured with the presses.

Filtration data of the settlings at Waialua Agricultural Company. Date of tests, April 21, 22, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.6	800 cc.	6.8	1075 cc.	180 gms.	3/16″	50 secs.	2.9
750 "	...	...	6.8	2050 "	240 "	1/4 ″	55 "	2.1
700 "	8.5	850 "	6.9	1250 "	150 "	1/8 ″	45 "	2.0
...	9.0+	825 "	6.8	1250 "	245 "	1/4 ″	30 "	3.3
700 "	8.7	800 "	6.8	1000 "	83 "	3/32″	40 "	1.5
...	9.0+	950 "	6.8	1200 "	200 "	3/16″	50 "	2.9
Av. 710 cc.	8.8	845 cc.	6.8	1300 cc.	183 gms.	3/16″	45 secs.	2.45

One of the characteristics of the settlings at this factory is the higher filtration rate of the settlings as discharged from the settlers. The effect of liming and the phosphoric acid treatment results in filtration rates approximately the same as found at Waipahu. The cake formed during these tests was 3/16″ in thickness and cracked in 45 seconds. This fairly high cracking time indicates that the cake is not very porous. The suspended solids in the settlings vary considerably, from 1.5 to 3.3 per cent.

Filtration data of the settlings at Kahuku Plantation Company. Date of tests, April 25, 26, 27, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.8	850 cc.	6.8	1000 cc.	175 gms.	5/32″	35 secs.	2.9
750 "	8.6	1150 "	6.8	1300 "	270 "	7/32″	30 "	3.3
775 "	8.6	850 "	6.8	1050 "	185 "	3/16″	40 "	3.0
800 "	8.7	950 "	6.8	1200 "	230 "	1/4 ″	35 "	3.2
750 "	..	...	6.8	1225 "	215 "	3/16″	40 "	3.0
725 "	9.0+	850 "	6.9	1075 "	150 "	1/8 ″	..	2.5
575 "	8.6	775 "	6.7	975 "	135 "	1/8 ″	35 "	2.4
800 "	8.5	875 "	..	1200 "	200 "	3/16″	40 "	2.8
Av. 730 cc.	8.7	900 cc.	6.8	1130 cc.	195 gms.	5/32″	36 secs.	2.9

The filtration rate of the untreated settlings at this factory is considerably higher than that usually found at Waipahu. However, after liming and acidifying with phosphoric acid, the filtration rate is less than the average. The cake was only 5/32″ in thickness, cracking in 36 seconds. This rather low cracking time indicates a fairly porous cake. The suspended solids in the settlings are quite uniform, varying from 2.4 to 3.3 per cent, and averaging 2.9 per cent.

Filtration data of the settlings at Maui Agricultural Company. Date of tests, May 3, 4, 5, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
800 cc.	8.6	800 cc.	6.8	950 cc.	140 gms.	1/8 ″	60 secs.	2.5
675 "	8.7	675 "	6.9	925 "	132 "	3/32″	65 "	2.5
875 "	8.5	925 "	6.9	1050 "	93 "	1/16″	55 "	1.6
575 "	8.8	600 "	6.8	750 "	240 "	3/16″	50 "	4.8
1050 "	8.6	1125 "	6.8	1250 "	92 "	1/16″	50 "	1.4
Av. 795 cc.	8.7	825 cc.	6.85	985 cc.	140 gms.	3/32″	56 secs.	2.56

Although the settlings at this factory are returned to the mill, it seemed desirable to secure some data at this factory because of the particular conditions which exist there. The juices are strained through a Peck strainer, covered with a 125-mesh screen. The limed juices are settled in Dorr clarifiers, using both primary and secondary units. The settlings from the Dorr were then resettled. In spite of this long settling cycle, a large volume of settlings was secured. The average filtration rate of the untreated settlings was higher than any tested at that time. It is interesting to note that the response to lime is very slight, while the response to the phosphoric acid treatment is slightly greater. As was to be expected, a thin cake was formed, averaging 3/32″, and cracking in 56 seconds. This cracking time is

quite high and is characteristic of this type of settlings. From all experience with fine strained juices, the settlings can not be satisfactorily handled in the filter press. Perhaps were it possible to construct a filter with very thin frames, the settlings could then be filtered.

Filtration data of the settlings at Pioneer Mill Co. Date of tests, May 6, 7, 9, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
360 cc.	8.8	475 cc.	6.8	1350 cc.	420 gms.	7/16″	30 secs.	4.7
350 "	9.0	750 "	6.9	1600 "	260 "	1/4 ″	25 "	2.8
650 "	9.0	950 "	6.8	1375 "	175 "	3/16″	30 "	2.3
375 "	8.5	850 "	6.8	2350 "	550 "	5/8 ″	30 "	3.3
725 "	9.0	1400 "	6.8	1900 "	700 "	3/4 ″	25 "	5.0
Av. 492 cc.	8.9	885 cc.	6.8	1715 cc.	420 gms.	7/16″	28 secs.	3.6

The filtration characteristics of the settlings at this factory were improved to a very great extent by the Borden process. The filtration rate of the untreated settlings was very low in some tests, the average being about the same as that found at Oahu. On liming these settlings the filtration rate increased approximately 80 per cent. When these settlings were then acidified to 6.8 pH with phosphoric acid, the rate was increased almost 100 per cent above that of the limed settlings. These high filtration rates compare well with the best that were found at Oahu Sugar Co.

An average cake of 7/16″ in thickness was formed, and although the cake was about five times as thick as that formed at Maui Agricultural Co., it cracked in half the time. The influence of the cush cush on the porosity of the cake is well brought out in this example.

Filtration data of the settlings at Wailuku Sugar Co. Date of tests, May 10, 11, 12, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.8	700 cc.	6.8	900 cc.	125 gms.	1/8 ″	50 secs.	2.4
700 "	9.0	825 "	6.8	975 "	133 "	1/8 ″	55 "	2.4
1175 "	8.6	1275 "	6.9	1550 "	154 "	3/16″	50 "	1.8
600 "	8.8	725 "	6.9	825 "	100 "	3/32″	50 "	2.2
600 "	8.8	675 "	6.8	675 "	80 "	3/32″	50 "	2.0
500 "	8.8	600 "	6.8	675 "	80 "	3/32″	50 "	2.0
725 "	8.9	800 "	6.7	875 "	90 "	3/32″	55 "	1.8
Av. 700 cc.	8.8	800 cc.	6.8	925 cc.	109 gms.	7/64″	51 secs.	2.1

Although the untreated settlings at this factory had a filtration rate which was somewhat better than that found at the Oahu Sugar Co., after liming these settlings there was only a slight improvement in the filtration rate. After adding phosphoric acid, the filtration rate increased slightly but was considerably lower than the average found at Oahu Sugar Co. A thin cake was formed, averaging only 7/64″ in thickness, and cracking in 51 seconds. Considerable difficulty was experienced in filtering these settlings in the presses. This will be more fully discussed in another part of this report.

Filtration data of the settlings at the Lihue Plantation Co. Date of tests, May 16, 17, 1927:

Untreated Settlings	Limed Settlings		Treated Settlings by the Borden Process					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
400 cc.	8.5-8.8	500 cc.	6.8	800 cc.	...	1/4 ″	47 secs.	..
450 ″	″	700 ″	6.8	1050 ″	115 gms.	1/8 ″	50 ″	2.0
...	″	700 ″	6.8	890 ″	...	1/16″	..	..
700 ″	″	950 ″	6.8	1050 ″	125 ″	1/8 ″	45 ″	2.1
700 ″	″	800 ″	6.9	1200 ″	...	3/16″	55 ″	..
675 ″	″	900 ″	6.9	1025 ″	149 ″	1/8 ″	50 ″	2.5
575 ″	″	750 ″	7.0	825 ″	93 ″	3/32″	..	2.0
650 ″	″	700 ″	6.8	1050 ″	135 ″	1/8 ″	50 ″	2.3
Av. 600 cc.	8.65	750 cc.	6.85	990 cc.	123 gms.	1/8 ″	50 secs.	2.2

The settlings at this factory after being discharged from the continuous settlers are resettled. Even after resettling they are low in suspended solids. The filtration rate on the untreated settlings is a little below the average. There is only a slight response to lime and phosphoric acid, the filtration rate for the Borden-treated settlings being considerably below the average. A thin cake was formed, averaging only ⅛″ in thickness, and cracking in 50 seconds. For a cake of this thickness this is a long cracking time, indicating a cake that is not very porous.

Filtration data of the settlings at Kekaha Sugar Company. Date of tests, April 4, 5, 6, 7, 1927:

Untreated Settlings	Limed Settlings		Treated Settlings by the Borden Process					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
700 cc.	8.6	850 cc.	6.8	1100 cc.	150 gms.	1/8 ″	50 secs.	2.4
675 ″	8.7	900 ″	6.9	1200 ″	145 ″	1/8 ″	55 ″	2.2
900 ″	8.6	1180 ″	6.8	1380 ″	160 ″	1/8 ″	45 ″	2.0
675 ″	8.6	925 ″	6.8	1300 ″	200 ″	3/16″	45 ″	2.7
800 ″	8.6	1050 ″	6.8	1450 ″	240 ″	1/4 ″	40 ″	3.0
800 ″	9.0	900 ″	6.8	1100 ″	192 ″	3/16″	47 ″	2.9
800 ″	8.5	900 ″	6.8	1100 ″	180 ″	3/16″	43 ″	2.8
625 ″	8.7	775 ″	6.9	950 ″	200 ″	3/16″	50 ″	3.5
710 ″	8.7	950 ″	6.8	1300 ″	125 ″	1/8 ″	50 ″	1.7
Av. 743 cc.	8.7	940 cc.	6.8	1210 cc.	177 gms.	3/16″	50 secs.	2.6

The filtration rate of the untreated settlings at this factory is higher than the average secured at Oahu Sugar Co. There is a fair response to lime and the phosphoric acid treatment. The filtration rate of the latter is somewhat less than the average. A cake averaging 3/16″ in thickness and cracking in 50 seconds was formed. Such a long cracking time indicates that the cake is not very porous. The suspended solids in the settlings are fairly low; these will undoubtedly increase when the juices are settled in a Dorr clarifier.

Filtration data of the settlings at Hawaiian Sugar Company. Date of tests, May 18, 19, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
475 cc.	..	...	6.8	775 cc.	400 gms.	7/16″	35 secs.	6.6
675 "	8.6	750 cc.	6.8	1375 "	375 "	3/8 ″	30 "	4.2
600 "	8.7	900 "	6.9	900 "	286 "	1/4 ″	..	3.8
725 "	8.7	1025 "	6.9	1550 "	546 "	1/2 ″	40 "	5.2
*1150 "	8.8	1480 "	6.8	1850 "	1000 "	1 ″	30 "	7.0
*1050 "	..	...	6.7	1750 "	1250 "	1 1/4 ″	40 "	8.3
Av. 779 cc.	8.7	1039 cc.	6.8	1370 cc.	643 gms.	5/8 ″	35 secs.	6.0

By far the thickest settlings were found here at Hawaiian Sugar Company. The suspended solids in some samples were as high as 10 per cent. In this condition no tests could be made, so the writer diluted these settlings down to 7.0 to 8.0 per cent with hot clarified juice. The treated settlings on the average showed a very good filtration rate, besides forming a very thick cake, averaging ⅝″. An individual sample was 1¼″ in thickness. These thick cakes cracked in 35 seconds, indicating a highly porous condition.

Filtration data of the settlings at Makee Sugar Company. Date of tests, May 20, 21, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
885 cc.	8.5-8.8	1475 cc.	6.9	1200 cc.	97 gms.	1/8 ″	37 secs.	1.5
475 "	"	800 "	6.8	750 "	350 "	3/8 ″	..	6.3
1100 "	9.0	1325 "	6.8	1200 "	110 "	3/32″	35 "	1.6
700 "	8.5-8.8	1000 "	6.9	1030 "	128 "	1/8 ″	40 "	2.2
685 "	"	1025 "	6.8	1085 "	152 "	1/8 ″	..	2.4
720 "	"	1025 "	6.9	1125 "	158 "	5/32″	40 "	2.5
800 "	"	1000 "	6.7	1050 "	123 "	3/32″	35 "	2.1
Av. 766 cc.	8.5-8.8	1090 cc.	6.8	1060 cc.	160 gms.	5/32″	37 secs.	2.7

* Diluted with clarified juice.

The characteristics of the settlings are quite different from the average. The rate of flow of the untreated settlings is considerably higher than the average found at Oahu Sugar Co. When these settlings were limed to 8.5 to 8.8 pH, a good increase in filtration rate was secured, but when these limed settlings were acidified with phosphoric acid to 6.8 pH, a small decrease in filtration rate was secured. With the exception of one sample, these settlings are very thin or low in suspended solids. The one sample which ran over 6.0 per cent was taken after the boiling house was shut down for a few hours. Undoubtedly, with a more efficient type of settling tanks, thicker settlings could be secured. A fairly thin cake was formed, averaging 5/32″ in thickness and cracking in 37 seconds.

Filtration data of the settlings at Hawaiian Agricultural Company. Date of tests, June 1, 2, 1927:

Untreated Settlings	Limed Settlings		Treated Settlings by the Borden Process					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	8.6	900 cc.	6.8	1025 cc.	133 gms.	1/8 ″	40 secs.	2.3
...	8.8	810 "	6.8	1050 "	175 "	3/16″	..	2.8
800 cc.	9.0	1050 "	6.9	1175 "	140 "	1/8 ″	45 "	2.2
900 "	8.7	1075 "	6.8	1650 "	400 "	3/8 ″	40 "	3.9
...	8.5-8.8	1000 "	6.8	1075 "	220 "	7/32″	..	3.4
750 "	8.5-8.8	750 "	6.7	900 "	190 "	3/16″	..	3.4
725 "	8.7	775 "	6.8	900 "	180 "	3/16″	40 "	3.3
Av. 794 cc.	8.8	910 cc.	6.8	1110 cc.	205 gms.	3/16″	41 secs.	3.0

The filtration rate of the untreated settlings at this factory was considerably higher than that found at Oahu Sugar Co. The filtration rate of the limed settlings is about normal, but on the acidified settlings the filtration rate is considerably less than the average. The cake averaged 3/16″ in thickness and the time of cracking was 41 seconds. The suspended solids in the settlings averaged 3.0 per cent during the time of these tests. This is the same as the average of the settlings for nineteen factories.

Filtration data of the settlings at Hilo Sugar Company. Date of tests, June 4, 1927:

Untreated Settlings	Limed Settlings		Treated Settlings by the Borden Process					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
1150 cc.	8.7	1775 cc.	6.8	1675 cc.	173 gms.	7/32″	40 secs.	1.9
900 "	8.5	1200 "	6.7	1400 "	327 "	3/8 ″	35 "	3.8
1050 "	8.6	1700 "	6.8	1700 "	165 "	3/16″	45 "	1.8
1000 "	8.7	1550 "	6.9	1600 "	200 "	7/32″	35 "	2.2
Av. 1025 cc.	8.6	1556 cc.	6.8	1600 cc.	218 gms.	3/16″	39 secs.	2.4

The average filtration rate of the untreated settlings at this factory is over 100 per cent higher than the average found at Oahu Sugar Company. When these settlings were limed to 8.6 pH the filtration rate increased to 1556 cc., which is considerably above the average for limed settlings. The treated settlings showed only a slight increase in the filtration rate. However, this is well above the average found at the various factories. The cake averaged 3/16″ in thickness and cracked in 39 seconds, indicating a fairly porous cake. The settlings are low in suspended solids.

Filtration data of the settlings at Waiakea Mill Company. Date of tests, June 6, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	9.0	800 cc.	6.8	780 cc.	240 gms.	1/4 ″	90 secs.	4.8
525 cc.	8.65	775 ʻʻ	6.9	800 ʻʻ	220 ʻʻ	3/16″	110 ʻʻ	4.3
675 ʻʻ	8.6	750 ʻʻ	6.8	750 ʻʻ	151 ʻʻ	1/8 ″	90 ʻʻ	3.3
525 ʻʻ	8.8	800 ʻʻ	6.8	825 ʻʻ	145 ʻʻ	1/8 ″	85 ʻʻ	3.0
Av. 575 cc.	8.8	781 cc.	6.8	789 cc.	189 gms.	3/16″	94 secs.	3.8

The settlings at this factory have the poorest filtering characteristics of any tested. There was a small response to lime and practically no further response when these settlings were acidified with phosphoric acid. The filtration rate of the treated settlings is about 40 per cent below the average found at Oahu Sugar Co. A cake 3/16″ in thickness and cracking in 94 seconds was formed on the test plate. The long time interval indicates that it is not porous. Considerable difficulty was experienced in handling these settlings in the filter presses. A high polarization in cake was secured. The settlings averaged 3.8 per cent suspended solids. This is 18 per cent higher than the average.

Filtration data of the settlings at Olaa Sugar Company. Date of tests, June 7, 8, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
750 cc.	8.5-8.8	800 cc.	6.8	1150 cc.	175 gms.	5/32″	45 secs.	2.6
650 ʻʻ	ʻʻ	950 ʻʻ	7.0	1100 ʻʻ	126 ʻʻ	1/8 ″	50 ʻʻ	2.0
700 ʻʻ	ʻʻ	800 ʻʻ	6.8	1000 ʻʻ	150 ʻʻ	5/32″	45 ʻʻ	2.6
...	9.0	800 ʻʻ	6.9	950 ʻʻ	178 ʻʻ	3/16″	40 ʻʻ	3.1
800 ʻʻ	8.5-8.8	800 ʻʻ	6.8	975 ʻʻ	...	3/16″	..	..
650 ʻʻ	ʻʻ	875 ʻʻ	6.8	975 ʻʻ	260 ʻʻ	7/32″	55 ʻʻ	4.0
650 ʻʻ	ʻʻ	800 ʻʻ	6.8	1000 ʻʻ	...	7/32″	..	..
650 ʻʻ	ʻʻ	850 ʻʻ	6.9	1075 ʻʻ	160 ʻʻ	3/16″	48 ʻʻ	2.4
730 ʻʻ	ʻʻ	825 ʻʻ	6.9	1100 ʻʻ	220 ʻʻ	7/32″	35 ʻʻ	3.3
Av. 700 cc.	8.7	835 cc.	6.85	1036 cc.	181 gms.	3/16″	45 secs.	3.0

The response to lime and phosphoric acid treatment of these settlings was considerably below that usually found at the Oahu Sugar Co. The cake averaged only 3/16″ in thickness and cracked in 45 seconds. This indicated that the cake was not very porous. The suspended solids in the settlings varied from 2.0 to 4.0 per cent, averaging 3.0 per cent. Considerable difficulty was experienced in handling these settlings in the filter presses, producing a press cake high in polarization. The characteristics of these settlings will be more fully discussed in another part of this report.

Filtration data of the settlings at Laupahoehoe Sugar Company. Date of test, June 9, 1927:

Untreated Settlings	Limed Settlings		Treated Settlings by the Borden Process					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
1075 cc.	8.5-8.8	1275 cc.	6.7	1400 cc.	...	5/16″	..	..
1375 "	"	1400 "	6.8	1650 "	309 gms.	5/16″	25 secs.	3.1
1150 "	"	1375 "	6.9	1550 "	...	7/16″	..	..
1250 "	"	1400 "	6.8	1500 "	340 "	7/16″	25 "	4.2
1450 "	"	1500 "	6.8	1600 "	...	5/16″	..	..
Av. 1260 cc.	8.65	1390 cc.	6.8	1540 cc.	325 gms.	3/8 ″	25 secs.	3.6

The filtration rate of the untreated settlings at this factory is almost 200 per cent greater than that found at Oahu Sugar Co. While there is only a small response to lime and phosphoric acid, the filtration rate of the limed settlings, as well as the treated settlings, are both higher than the average. The cake averaged ⅜″ in thickness and cracked in 25 seconds. Such a cake is very porous and can be easily sweetened off. Exceptionally low polarizations in press cake have been reported from this factory.

The cane at this factory is all flumed to the mill. At the time of this visit, the cane was very clean and practically free from trash. The absence of the soil and trash in this cane undoubtedly explains the exceptionally good filtration characteristics of these settlings.

Filtration data of the settlings at Honokaa Sugar Company. Date of tests, June 10, 1927:

Untreated Settlings	Limed Settlings		Treated Settlings by the Borden Process					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
...	9.0	1750 cc.	6.8	1350 cc.	170 gms.	3/16″	25 secs.	2.2
1175 cc.	8.8	1375 "	6.8	1425 "	235 "	1/4 ″	30 "	2.8
875 "	9.0	1500 "	..	....	...	...	..	..
1650 "	8.8	1930 "	6.8	1600 "	152 "	3/16″	23 "	2.2
500 "	8.65	830 "	6.8	1200 "	100 "	3/32″	35 "	1.5
Av. 1050 cc.	8.9	1477 cc.	6.8	1394 cc.	164 gms.	3/16″	30 secs.	2.2

The filtration characteristics of the settlings at this factory are of two distinct types. The one, which is typical of many factories, has a low filtration rate on the untreated settlings and responds to both lime and phosphoric acid treatment, yielding an increase in filtration rate in the limed settlings and a further increase in the treated settlings.

The other type has filtration characteristics similar to those found at Makee Sugar Co. A high filtration rate is secured on the untreated settlings and a fair increase in filtration rate in the limed settlings, but the acidified settlings show a decrease in filtration rate. The cake averaged 3/16″ in thickness and cracked in 30 seconds, indicating a high degree of porosity.

Filtration data of the settlings at Hawi Mill and Plantation Co. Date of tests, June 14, 15, 1927:

Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS					
Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings
575 cc.	8.5-8.8	850 cc.	6.7	925 cc.	150 gms.	1/8 ″	45 secs.	2.8
950 ″	″	1050 ″	6.8	1175 ″	145 ″	1/8 ″	50 ″	2.2
850 ″	″	1000 ″	6.8	1100 ″	163 ″	5/32″	45 ″	2.6
950 ″	″	1100 ″	6.9	1110 ″	155 ″	5/32″	50 ″	2.4
Av. 831 cc.	8.5-8.8	1000 cc.	6.8	1080 cc.	153 gms.	5/32″	48 secs.	2.5

A fairly high filtration rate was secured on the untreated settlings at this factory. The average of four tests was approximately 90 per cent higher than that generally found at Oahu Sugar Co. A fair increase in the filtration rate was found in the limed settlings. In the treated settlings the filtration rate was increased only slightly. The average is about 25 per cent below the average for treated settlings at Oahu Sugar Co. The cake averaged 5/32″ in thickness and cracked in 48 seconds. The suspended solids in the settlings were only 2.5 per cent, but they were fairly uniform in density.

The filtration data from the various factories have been classified into six groups. While there are some variations within each classification, the filtration characteristics of the settlings in each group have some specific difference from the other groups.

Factory	Untreated Settlings	Limed Settlings		TREATED SETTLINGS BY THE BORDEN PROCESS						
	Volume of filtrate	pH	Volume of filtrate	pH	Volume of filtrate	Weight of cake	Thickness of cake	Time of crack.	% Sus. Solids in settlings	Fiber % cake solids
Oahu	440 cc.	8.7	874 cc.	6.8	1375 cc.	360 gms.	3/8 "	30 secs.	4.1	33.3
Honolulu	475 "	8.6	875 "	6.8	1167 "	245 "	1/4 "	32 "	3.45	27.9
Pioneer	492 "	8.9	885 "	6.8	1715 "	420 "	7/16"	28 "	3.6	44.6
GROUP I Average	469 cc.	8.7	878 cc.	6.8	1419 cc.	342 gms.	3/8 "	30 secs.	3.7	35.3
Ewa	(900 cc.)	8.8	900 cc.	6.9	1260 cc.	131 gms.	1/8 "	48 secs.	1.8	14.8
Waialua	710 "	8.8	845 "	6.8	1300 "	183 "	3/16"	45 "	2.45	20.6
Kahuku	730 "	8.7	900 "	6.8	1130 "	195 "	5/32"	36 "	2.9	25.0
Kekaha	743 "	8.7	940 "	6.8	1210 "	177 "	3/16"	50 "	2.6	20.0
H. S. Co.	779 "	8.8	1039 "	6.8	1370 "	643 "	5/8 "	35 "	6.0	38.0
H. A. Co.	794 "	8.8	910 "	6.8	1110 "	205 "	3/16"	41 "	3.0	27.3
Olaa	700 "	8.65	834 "	6.85	1036 "	181 "	3/16"	45 "	3.0	21.0
GROUP II Average	743 cc.	8.75	910 cc.	6.83	1202 cc.	245 gms.	1/4 "	43 secs.	3.1	23.8
Laupahoehoe	1260 cc.	8.65	1390 cc.	6.8	1540 cc.	325 gms.	3/8 "	25 secs.	3.6	39.6
Hilo	1025 "	8.6	1556 "	6.8	1600 "	218 "	3/16"	39 "	2.4	45.7
Hawi	831 "	8.65	1000 "	6.85	1080 "	153 "	5/32"	48 "	2.5	26.1
GROUP III Average	1039 cc.	8.63	1315 cc.	6.82	1407 cc.	232 gms.	1/4 "	37 secs.	2.8	37.1
Honokaa	1050 cc.	8.9	1477 cc.	6.8	1394 cc.	164 gms.	3/16"	30 secs.	2.2	26.3
Makee	766 "	8.65	1090 "	6.8	1060 "	160 "	5/32"	37 "	2.7	15.5
GROUP IV Average	908 cc.	8.78	1283 cc.	6.8	1227 cc.	162 gms.	11/64"	33.5 secs.	2.45	20.9
Lihue	600 cc.	8.65	750 cc.	6.85	990 cc.	123 gms.	1/8 "	56 secs.	2.6	21.2
Wailuku	700 "	8.8	800 "	6.8	925 "	109 "	7/64"	51 "	2.1	18.5
GROUP V Average	650 cc.	8.72	775 cc.	6.82	958 cc.	116 gms.	7/64"	53.5 secs.	2.35	19.9
M. A. Co.	795 cc.	8.7	825 cc.	6.85	985 cc.	140 gms.	3/32"	56 secs.	2.6	3.0
Waiakea	575 "	8.8	781 "	6.8	789 "	189 "	3/16"	94 "	3.8	11.5
GROUP VI Average	685 cc.	8.75	803 cc.	6.82	887 cc.	164 gms.	5/32"	75 secs.	3.2	7.25
AVERAGE OF ALL	748 cc.	8.65	983 cc.	6.8	1212 cc.	227 gms.	7/32"	44 secs.	3.0	25.3

In the first group of factories we have Oahu Sugar Co., Honolulu Plantation Co., and Pioneer Mill Co. The filtration rate of the untreated settlings is very low. The average for the three factories is 469 cc. After liming to 8.7 pH, the filtration rate of the settlings is increased to 878 cc. This amounts to an increase in filtration rate of 87 per cent. The phosphoric acid treated settlings show a further increase in filtration rate amounting to 110 per cent of the rate for untreated settlings. At each of these factories a thick cake was formed, averaging 3/8″ in thickness. The average time of cracking is 30 seconds, indicating a high degree of porosity.

The settlings at all three of these factories are suited to an Oliver Continuous Filter.

There are seven factories in the second group. These are as follows: Ewa Plantation Co., Waialua Agricultural Co., Kahuku Plantation Co., Kekaha Sugar Co., Hawaiian Sugar Co., Hawaiian Agricultural Co., Olaa Sugar Co. The chief differences in the characteristics of this group over the first group are the higher filtration rates on the untreated settlings, averaging 743 cc. as against 469 cc. The filtration of the limed settlings is 910 cc., which is close to that of the first group. When the settlings are acidified, the average filtration rate is 1202 cc. This is considerably smaller than the filtration rate of the first group. While the average thickness of cake for this group is 1/4″, this is due to the exceptional thickness of the cake at Hawaiian Sugar Co. If this one factory is omitted, the average becomes 11/64″. The average time of cracking is 43 seconds, indicating that the cake is fairly porous. The per cent suspended solids in the settlings for this group is influenced by the high figure for Hawaiian Sugar Co. With this factory included, the average is 3.1 per cent; without, it is 2.6 per cent. Of the group, the settlings at Hawaiian Sugar Co. have characteristics which are best suited to an Oliver filter. The high filtration rate, 1370 cc. on acidified settlings, the cake 5/8″ in thickness and a cracking time of 35 seconds, are all characteristics favorable to a continuous filter.

The settlings at Olaa Sugar Co. have the poorest characteristics of any in the group. The filtration rate of the untreated settlings, limed settlings and Borden treated settlings is 700 cc., 834 cc., 1036 cc. respectively. The cake averaged 3/16″ in thickness and cracked in 45 seconds, indicating only a fair degree of porosity.

With the exception of Hawaiian Sugar Co., the settlings at the other factories were not suited to an Oliver filter. The chief deficiency in each case was the amount of fiber or cush cush present in the suspended solids. A discussion of the concentration of the fiber in the suspended solids in settlings necessary to secure good results on an Oliver filter is presented in another part of this report.

In the third group are three factories: Laupahoehoe Sugar Co., Hilo Sugar Co., Hawi Mill & Plantation Co. The average filtration rate of the untreated settlings in this group is 1039 cc. This is over 120 per cent more than the average for the first group. The limed settlings show an increase in filtration rate which is also considerably higher than that found in either the first or second groups. The filtration rate of the Borden treated settlings shows only a fair increase: the average is slightly below that of the first group. The outstanding characteristics of the

settlings in this group are the high filtration rates on the untreated settlings, the fairly large increase due to liming the settlings, and the comparatively small increase in filtration rate when treated with phosphoric acid. The cake averaged ¼″ in thickness and cracked in 37 seconds.

Of the three factories in this group, the filtration characteristics of the settlings at the Laupahoehoe Sugar Co. are the best of any settlings tested. The writer is of the opinion that at times these settlings would be successfully filtered on an Oliver filter without any treatment, or only a partial treatment.

The characteristics of the settlings at Hilo Sugar Co. are such that it is doubtful whether they could be handled on an Oliver filter without some modification. Even though the per cent fiber in the suspended solids is well above 30 per cent, the concentration of the suspended solids in the settlings is very low at times. This would produce a cake on an Oliver filter which would be too thin to handle satisfactorily. For this reason a longer cycle on the Oliver filter might be required.

The fiber content of the settlings at Hawi Mill & Plantation Co. would have to be increased to make them suited for an Oliver filter.

In the fourth group are two factories: Honokaa Sugar Co., Makee Sugar Co. The chief characteristics of these settlings are the relatively high filtration rate of the untreated settlings and the decrease in filtration rate of the treated settlings from the filtration rate of the limed settlings. These are the only two instances where this occurs.

The average filtration rate of the untreated settlings is 908 cc. This is almost 100 per cent higher than that of the first group and only about 10 per cent lower than that of the third group, which has the highest filtration rate on untreated settlings of any tested. After liming and then treating with phosphoric acid the rates were 1283 cc. and 1227 cc. respectively, showing a decrease of 56 cc. While this decrease is small, it is, nevertheless, interesting. The cake averaged 11/64″ in thickness and cracked in 33.5 seconds, indicating a porous cake. The settlings at these factories could be handled on an Oliver filter, provided the fiber content in the cake solids was increased to the proper concentration.

In the fifth group are two factories: Lihue Plantation Co. and Wailuku Sugar Co. While the average filtration rate of untreated settlings is 650 cc., the limed settlings and treated settlings have the respective filtration rates 775 cc. and 958 cc. The failure to respond to any great extent to liming or to treating with phosphoric acid is the chief characteristic of these settlings. An exceptionally thin cake was formed in both cases, averaging 7/64″ in thickness and cracking in 53.5 seconds. This is an unusually long time interval for such a thin cake, indicating that the cake was not very porous. The filtration characteristics of these settlings would have to be improved considerably to make them suitable for an Oliver filter.

In the sixth group are Maui Agricultural Co. and Waiakea Mill Co. It is largely because the settlings at these two factories are extremely low in fiber that they were grouped together. The filtration rate of the untreated settlings is slightly more than the previous group, and is almost 50 per cent higher than the first group. But the response to lime and acid is very low, resulting in a filtration rate of 803 cc. for limed settlings and 887 cc. for treated settlings. This latter figure is the

lowest of any group average, being 60 per cent of the maximum which is found in the first group. The cake averaged 5/32" in thickness, with an average cracking time of 75 seconds, indicating that the cake was not porous. The filtration characteristics of the settlings at both these factories are unsuited for an Oliver filter. The fiber content would have to be increased to the proper concentration.

The main reason why the settlings in the majority of the factories visited are not suited to an Oliver filter in its present application in cane sugar factories is because the fiber in the suspended solids is too low. When the settlings contain 3 per cent or more suspended solids, it has been found that the fiber should be at least 28 to 30 per cent of the suspended solids. This is equivalent to approximately .9 to 1.0 per cent on the settlings. In numerous tests at Waipahu, it was observed that as the fiber content decreases below 28 to 30 per cent of the suspended solids, the settlings become more difficult to handle on the Oliver filter. The capacity is decreased, the polarization of the cake as discharged is increased, and the frequency with which the cloth must be washed is increased.

The data secured at Hilo Sugar Company indicate that as the per cent suspended solids in the settlings decreases below 3.0 per cent, the per cent fiber in the suspended solids must be increased. From this it seems that the fiber concentration should be at least 1.0 per cent of the settlings, when the suspended solids in the settlings are 3.0 per cent or less. With concentrations of suspended solids greater than 3.0 per cent, the fiber should be, as previously mentioned, 28 to 30 per cent of the suspended solids.

The reason for this is that when the settlings contain less than 3.0 per cent suspended solids, a concentration of fiber of 1.0 per cent on settlings is necessary to secure a cake of suitable thickness and porosity on the Oliver filter.

Oliver Filter Operation at Olaa:

During the past year (1928) an Oliver filter was installed at the Olaa Sugar Company. It was ready for operation on April 7. The filtration tests made on the settlings at Olaa in June, 1927, indicated that the per cent fiber in the cake solids would have to be increased in order to secure satisfactory results on the Oliver filter. In order to verify these predictions, attempts were made to operate the filter on these settlings before any change in the mill screens was made. At this time a No. 4 screen, having 225 perforations per square inch, was in use. This is the same size screen that was used last year. The results on the Oliver filter were not satisfactory when these settlings were filtered. The capacity was low, the cake was thin and difficult to sweeten off. After a few hours running it was necessary to stop and wash the cloth. The fiber in the cake solids was only 18.5 per cent. These results coincide perfectly with the writer's prediction a year ago.

A No. 7 screen, having 144 perforations per square inch, was then installed to replace the No. 4 screen. This increased the fiber content to 23.5 per cent on cake solids. There was some improvement both in capacity as well as thickness of cake, but the results were still unsatisfactory. A No. 10 screen, having 64 perforations per square inch, was then installed. With the installation of this coarser screen the fiber in the cake solids was increased to 29 per cent and corrected all the

difficulties which had been encountered. The capacity was increased to a point which may be considered satisfactory, approximately 250-300 cubic feet per hour. The cake was between ¼″ and ½″ in thickness and was sufficiently porous so that it could be sweetened off to a reasonable polarization.

Commencing Sunday night, April 22, the Oliver filter became an integral part of the filter press station. During the first week the filter averaged approximately 55 per cent of all the settlings, amounting to 5500 cubic feet of settlings in 24 hours. This is equivalent to 38 tons cane per hour. The average polarization was 1.28 per cent. The second week that the filter was in continuous operation the capacity dropped to approximately 4500 cubic feet per day, corresponding to about 45 per cent of the total settlings, equivalent to 31.5 tons cane per hour. The main reason for this reduction in capacity was that the fiber content in the cake solids was only 23-26 per cent. There was a large proportion of D 1135 cane ground during the week. The fiber in this cane does not produce as much cush cush as other varieties of cane do.

There is another factor which influenced the capacity of the filter; the cloth with which the drum was covered was too heavy. A heavy cloth will produce a very clear filtrate, but the capacity is less than when a more open cloth is used. It is also more difficult to keep it clean. It is more than likely that there is a gradual accumulation of small particles in the cloth which cannot be removed by scrubbing with brushes.

During the third week, the Oliver filter was covered with a lighter weight cloth. Mr. Giacometti informed the writer that the settlings, corresponding to 120 tons of sugar per day (24 hours), were handled by the Oliver filter. This is equivalent to 6600 cubic feet of settlings, or 48 tons cane per hour.

This work at Olaa has shown quite conclusively that while the filtration characteristics of settlings may be unsuited for an Oliver filter, they can be improved and made suitable by increasing the per cent fiber in the suspended matter in the mixed juice. In this particular case, a sufficient amount of fiber could be introduced in the mixed juice by simply using coarser screens in the drag conveyor. The question arises whether under all conditions there will be sufficient fiber in a fine state of division formed so that this simple expedient will prove satisfactory.

There are a number of factors which tend to influence this: these are, the milling equipment, the variety of cane, and the condition of the cane. For any given variety of cane, it seems that a mill equipped with a shredder will produce more cush cush than a mill without a shredder. The grooving and the pressure on the rolls also influence the quantity of cush cush that is formed.

With the same milling equipment, different varieties of cane will produce varying amounts of cush cush. For example, D 1135 produces less cush cush than either H 109 or Yellow Caledonia. The same variety of cane will produce more cush cush in the summer months than in the winter months. The reason for this is that the fiber in the cane becomes more brittle in the dry weather. These factors all tend to influence the amount of cush cush which is formed. It is for these reasons that the writer hesitates to state definitely that by changing the size of the mill screen, sufficient fiber can always be added to the mixed juice so the filtration characteristics of the settlings will be suited for an Oliver filter.

An Explanation of the Reactions Which Take Place During the Borden Process of Treating Settlings:

Data are presented in the following pages in an attempt to explain the reactions which take place when settlings are subjected to the Borden treatment. In the filtration tests on untreated settlings we do not find any correlation between the volume of filtrate and the per cent fiber in the suspended solids. For example, the untreated settlings at Oahu Sugar Company had a filtration rate of 440 cc., and at Laupahoehoe Sugar Company a filtration rate of 1300 cc. The fiber in the suspended solids at Oahu Sugar Company is 33.3 per cent, while at Laupahoehoe it is 39.6 per cent. Both of these are high in fiber, yet before treatment the settlings at Oahu have the lowest filtration rate of any tested, while the settlings at Laupahoehoe have the highest filtration rate. After they have been treated by the Borden process the filtration rates are practically the same. The settlings at Oahu show a large increase in filtration rate, while the settlings at Laupahoehoe Sugar Company show only a small improvement.

In view of the above data, it is quite logical to conclude that some substance or substances are present in the Oahu settlings in greater concentrations and that they retard filtration. Further, by the Borden treatment their physical or chemical properties are changed so they do not retard filtration.

The filtration data secured at the various factories have shown that on untreated settlings from flumed cane, a very much greater filtration rate will be secured than on the untreated settlings from non-flumed cane. The settlings at Laupahoehoe Sugar Company contain more ether-soluble matter, such as cane wax, etc., than the settlings at Oahu. From this fact it does not seem possible that the ether-soluble matter entered into the reaction. The writer has never been able to establish any correlation between the ether-soluble content and the filtration characteristics of settlings.

There is a difference in the appearance of the settlings at Oahu and Laupahoehoe. The untreated settlings at Oahu Sugar Company resemble a smooth, creamy mass. The suspended particles appear to have lost their individual form and seem to be diffused in a gelatinous substance. After treatment, the particles regain their individual form. At Laupahoehoe, the suspended particles in the untreated settlings have not lost their individual form. In appearance they resemble the settlings at Oahu Sugar Co., after treatment.

It occurred to the writer that a study of the inorganic salts in press cake might explain the reactions which occur during the Borden treatment. The most important inorganic components in press cake are iron (Fe), aluminum (Al), calcium (Ca) and magnesium (Mg). The salts are phosphates, sulphates, hydroxides, aluminates, silicates and salts of organic acids. Besides these simple combinations there are undoubtedly more complex forms in which Fe, Al and silica are combined. There may be several forms of silica present. It is because of these possible variations, both in chemical composition as well as physical conditions, that the orthodox methods of procedure in solving a problem could not be followed.

The writer studied the effect on filtration rate when varying amounts of inorganic salts, assumed to be present, were added to the settlings. Considerable

preliminary work was done in which the data were inconsistent. The reason for this was because the salts were either sufficiently acid or alkaline to produce changes in the pH of the settlings. To correct this, these salts were neutralized until the pH was about the same or close to that of the settlings. Only small amounts of these salts were added in order to approximate actual concentrations. The following tabulation gives the list of salts and the concentrations of the solutions used.

Salt Solutions	Gms. Salt per Liter	Gms. per cc.
Ferric chloride $FeCl_3$	81.11	.0279 Fe
Aluminum chloride $AlCl_3$..........	66.74	.0136 Al
Sodium aluminate.................	82.1	.051 Al_2O_3
Sodium silicate...................	61.1	.030 SiO_2
Magnesium chloride...............	95.24	.024 Mg
Potassium hydrogen phosphate....	87.125	.071 P_2O_5
Calcium chloride..................	27.75	.010 Ca

In the series of tests given below the settlings were limed to 8.5 to 8.7 pH and then double superphosphate was added until the pH was reduced to about 7.4 pH. This was done so that almost the maximum rate of flow of settlings would be secured, and yet the pH would be approximately the same as that in the untreated settlings. With a high rate of flow the writer believed that more pronounced effects would be secured by the addition of these salts. In all tests 1300 cc. of settlings were used. The amount of salt solution and resulting concentration are given in the tabulation.

Test No.	Salt Solutions Added	Conc. % Settlings	Vol. of Filtrate
1	Blank (1300 cc. of settlings)	...	1225 cc.
2	" + 20 cc. $FeCl_3$	.043% Fe	1200 cc.
3	" + 40 cc. "	.086% Fe	1240 cc.
4	" + 40 cc. $AlCl_3$	.041% Al	1180 cc.
5	" + 80 cc. "	.083% Al	1210 cc.
6	" + 50 cc. $CaCl_2$	.039% Ca	1225 cc.
7	" + 100 cc. "	.078% Ca	1200 cc.
8	" + 25 cc. $MgCl_2$	.046% Mg	1195 cc.
9	" + 50 cc. "	.092% Mg	1200 cc.
10	" + 25 cc. Na_2SiO_3	.058% SiO_2	120 cc.
11	" + 50 cc. Na_2SiO_3	.116% SiO_2	100 cc.
12	" + 10 cc. $Na_2Al_2O_4$	.041% Al_2O_3	1175 cc.
13	" + 20 cc. "	.08 % "	1195 cc.
14	" + {20 cc. $Na_2Al_2O_4$; 25 cc. Na_2SiO_3}	{.083% Al_2O_3; .058% SiO_2}	1200 cc.

Inspection of the above tabulation shows that sodium silicate added to the settlings reduced the filtration rate from 1225 cc. to 120 cc. This sodium silicate was first acidified to about 7.5 pH and then added to the settlings. In view of the very pronounced retarding effect produced by this silicate, the writer studied this salt exclusively.

Sodium silicate in a water solution gives an alkaline reaction to phenolphthalein. When it is neutralized it first forms an acid silicate ($NaHSiO_3$). This salt in itself does not form any gelatinous precipitate in distilled water in the concentra-

tions used. However, in the presence of calcium hydroxide or magnesium hydroxide a voluminous and gelatinous precipitate is formed, and when mixed with cush cush it forms this cream-like mass resembling settlings before treatment.

Some of this gelatinous precipitate formed in clarified juice had a volume of 150-200 cc. When it was dried, it weighed only two grams, indicating a very great water-holding capacity, capable of covering a large surface. An analysis of this precipitate after drying showed that it contained 92 per cent silica (SiO_2). As there is no known silicate that contains such a large proportion of SiO_2, the writer has concluded that the precipitate consists largely or $SiO_2 \times H_2O$, and that the other substances present are simply occluded during its formation.

When this precipitate is formed in clarified juice and then is subjected to the Borden treatment, there is a gradual disappearance of the slimy, gelatinous precipitate, until, at 6.8 pH and below, there is no evidence of any being left.

A few tests were made to determine whether the silica in the settlings was redissolved when subjected to the Borden treatment. Samples were taken of the filtrate from untreated settlings, after liming and after the Borden treatment. If the silica was redissolved, then it was expected to be found in the filtrate.

	Silica % Ash in Filtrate	Ash % Filtrate	SiO_2 % Filtrate
Untreated settlings................	5.60	.41	.02
Limed settlings....................	2.27	.43	.01
Acidified settlings................	6.78	.44	.03

The silica shows an increase of .02 per cent in the filtrate from the treated settlings. Approximately 12.5 per cent of the silica in the settlings is redissolved by the Borden treatment. This percentage will vary greatly, depending on the type of silica present in the settlings. In the experiments conducted by the writer it was found that by adding very small amounts of silica under certain conditions, the filtration rate could be reduced considerably below any found. The data in this experiment indicate that there is a re-solution of silica when the settlings are acidified with phosphoric acid.

Another test was made in which samples were taken of the mixed juice, filtered mixed juice, filtered hot limed mixed juice, clarified juice, and the settlings both before and after treatment.

	SiO_2 % Ash	Ash % Juice	SiO_2 % Juice
Mixed juice......................	13.6	.38	.052
Filtered mixed juice..............	2.5	.29	.007
Filtered hot limed mixed juice......	3.97	.30	.012
Clarified juice....................	4.2	.31	.013
Filtrate untreated settlings........	5.45	.32	.017
Filtrate limed settlings...........	1.35	.35	.005
Filtrate acidified settlings.........	6.62	.33	.022

These analyses show that a large part of the silica in the mixed is in the suspended matter. During clarification a part goes into solution. In the settlings we have the same effect as noted in the previous experiment.

The writer has concluded that the more soluble silicates in the juices and suspended matter are transformed during the clarification process into this gelatinous form of silica. The important points have been summarized as follows:

A comparatively small quantity of the gelatinous silica has a very pronounced retarding effect on the filtration rate. Small quantities, representing only a part of

what is in settlings, will produce a filtration rate which is very much less than has been found in the poorest of settlings.

There is a close similarity to settlings in its behavior toward phosphoric acid. As the pH of the settlings is reduced from 8.5, there is a gradual disappearance, until, at 6.8 pH, there seems to be a complete disappearance.

This silica gel will form in the pH range encountered in clarification, and also at these temperatures and concentrations.

Were it possible to separate the various forms of silica or silicates in settlings, more direct data could be secured to substantiate or disprove this theory.

Filter Press Performance As Influenced By Fiber-Silica Ratio

As a part of the survey made on the filtration characteristics of the settlings, samples of press cake were collected from each of the factories. From these analyses, and also from the observations made at each factory, the writer wished to determine whether there were any outstanding differences in composition which would affect the filter press work.

The work at Oahu Sugar Company has shown the importance of fiber as a filter aid and cake former, and its value in producing a porous cake. Recent research work indicates that soluble silicates can be converted into a gelatinous condition during the clarification process. In this gelatinous condition the results show that it has a very pronounced retarding effect on filtration.

With this in mind, the writer determined fiber, ether-soluble, ash and silica on these press cake samples. The results were calculated to a sucrose-free, moisture-free basis. The ratio of fiber to silica has also been calculated, and in the tabulation which follows the data have been arranged according to this ratio. The sample of press cake having the highest ratio is first, and so on down. Settlings possessing the most favorable filtration characteristics would be in the upper portion of this table, while those with the poorest characteristics would be found in the lower portion of the table.

Per Cent Cake Solids

Factory	Fiber	Ether-Soluble	Ash	Silica	Fiber/Silica
Pioneer	44.6	12.7	18.0	2.2	20.3
Laupahoehoe	39.6	12.8	15.5	2.14	18.5
Hilo	45.7	10.9	19.7	4.10	11.1
Hawi	26.1	7.5	38.3	3.2	8.1
Oahu	33.3	11.3	26.8	4.9	6.7
Haw. Sugar	38.0	17.8	29.6	5.76	6.6
Makee	15.5	8.9	35.6	2.40	6.6
Honolulu Plt. Co.	27.9	13.8	32.7	4.67	6.0
Wailuku (July sample)	24.5	11.9	27.4	4.25	5.8
Ewa	14.8	9.7	32.6	2.60	5.7
Haw. Agr.	27.3	10.6	28.0	4.9	5.6
Waialua	20.6	7.9	28.9	4.92	4.2
Honokaa	26.3	8.2	41.0	6.72	3.94
Olaa	21.0	8.3	17.7	5.66	3.7
Kahuku	25.0	6.9	43.4	7.51	3.33
Kekaha	20.0	...	30.0	6.93	2.89
Wailuku (May sample)	18.5	9.4	35.2	6.72	2.77
Lihue	21.2	9.3	38.4	7.80	2.72
Waiakea	11.5	6.5	39.6	4.60	2.40

There are several other factors beside the filtration characteristics of the settlings which affect the filter press work. These are as follows: the filter press capacity available, the mechanical condition of the filter presses as well as the thickness of cake formed, the method of operation and the personal supervision. In view of all these factors, it is very difficult to compare the filter press work at the various factories on the basis of their filtration characteristics alone. Nevertheless, the above tabulation is very interesting, because in the upper half we find factories that are known to have good filtering settlings, while in the lower half are those known to have more or less difficult filtering settlings.

The writer had the opportunity to study the filtration characteristics of the settlings at Wailuku Sugar Co. during May and also July, 1927. To filter these settlings saisfactorily in May, excessive quantities of lime were used, while in July the settlings were filtered satisfactorily without the use of any extra lime. The analysis of the press cake shows a marked difference in the fiber/SiO_2 ratio.

	Per Cent Cake Solids			
	Fiber	Ash	Silica	Fiber/Silica
May sample	18.5	35.2	6.72	2.77
July sample	24.5	27.4	4.25	5.80

While the per cent fiber in the July sample has increased only 33 per cent, the fiber/SiO_2 ratio has more than doubled. This, the writer believes, accounts for the difference in the cake-forming properties.

According to Mr. Henderson, of the Lihue factory, the settlings at Lihue are very much more difficult to filter than at Makee. Lihue has 97 square feet of filtering surface, while Makee has 84 square feet filtering surface per ton cane per hour. This favors Lihue. An analysis of the press cake samples from these two factories follows:

	Per Cent Cake Solids			
Factory	Fiber	Ash	Silica	Fiber/SiO_2
Lihue	23.2	38.4	7.79	2.98
Makee	15.5	35.6	2.40	6.46

The press cake sample from Makee had only two-thirds of the fiber content of that from Lihue. However, the silica in the cake solids was only 30 per cent, which made the fiber/SiO_2 ratio for the press cake from Makee more than double that of Lihue. This difference in the fiber/SiO_2 seems to explain why the settlings at Makee can be filtered more readily than those at Lihue.

The data presented in a previous report, and also this report, have demonstrated that the fiber in the settlings serves as a cake-forming material as well as a filter aid; that some forms of silica can be converted into a gelatinous condition, and in this condition have a very pronounced retarding effect on filtration. This effect is more pronounced in some settlings than in others and can be corrected by treating the settlings with the Borden process. The ratio of the fiber to silica may serve as an index to differentiate between settlings having good filtration characteristics and settlings having poor filtration characteristics.

Acknowledgments

The writer is indebted to the managers and the personnel at these factories for their cooperation in carrying out the tests.

Annual Synopsis of Mill Data—1928

By W. L. McCleery

This Synopsis includes data from the forty factories of the Association. It represents all sugar produced from October 1, 1927, to approximately September 30, 1928, amounting to 897,416 tons, or an increase over the previous year of about 12 per cent. This calendar year does not coincide with the crop year for several factories. Figures for seven factories include portions of the previous crop ground after September 30, 1927. Five factories had not finished their 1928 crop on October 1, and one factory had started on its 1929 crop. Marks identifying these factories are shown in the first of the large tables.

There is very little change in the form of the Synopsis from that of last year. Data for roller grooving and returner bar settings, omitted the past two years, have been included in the large tables. The factories are listed in the tables in the order of their average sugar tonnage for the five previous years, unless otherwise noted.

Varieties of Cane

The major varieties of cane, ground to the extent of 1 per cent or more of the total crop, are shown in Table 1; also the ratio of individual varieties to the total crop for the past eleven seasons.

It will be noted that there are now only five major varieties. Lahaina and Striped Mexican have decreased to well under 1 per cent, and are now included in the tabulation of minor varieties. There has been a moderate increase in H 109, bringing its percentage up to 54.7, with its nearest competitor, Yellow Caledonia, showing a further decline to 20.7 per cent. D 1135, Yellow Tip, and Striped Tip have increased slightly. The general trend of the present five major varieties is the same as for several years.

With regard to the passing of Lahaina cane from the list of major varieties it may be mentioned that in 1918, the first year that this tabulation was started, Lahaina comprised 37.9 per cent of the total crop, and H 109, 4 per cent. During the next six years Lahaina was rapidly replaced by H 109, so that in 1924 Lahaina had decreased to 4.4 per cent of the crop, and H 109 had increased to 38.1 per cent. Last year the percentage of Lahaina was only 1.4 and this year it is .63 per cent. Striped Mexican, the other variety dropped from Table 1, never reached a high percentage, the highest being 3.1 in 1923. Since then the decline has been consistent to a low figure of .58 this year.

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

	H 109	Y. C.	D 1135	Yellow Tip	Striped Tip	Others
H. C. & S. Co.	99	..	1	..	..	..
Oahu	97	..	3	..	..	..
Ewa	100	..	..	..	..	..
Waialua	81	..	17	..	..	2
Maui. Agr.	91	..	..	..	..	9
Pioneer	92	..	1	..	..	7
Olaa	..	87	13	..	..	..
Haw. Sug.	91	..	8	..	..	1
Lihue	60	7	6	14	..	13
Honolulu	99	..	..	..	..	1
Onomea	..	80	3	16	..	1
Hilo	..	90	8	2	..	..
Kekaha	80	..	5	..	..	15
Haw. Agr.	..	39	49	..	..	12
Wailuku	91	..	4	..	..	5
Hakalau	..	74	3	23	..	..
Makee	56	17	..	16	..	11
Honokaa	3	6	81	..	..	10
McBryde	74	3	10	1	1	11
Laupahoehoe	..	32	37	31	..	..
Kahuku	91	8	..	..	..	1
Hamakua	..	20	72	8	..	..
Pepeekeo	..	86	6	8	..	..
Paauhau	3	1	77	17	..	2
Koloa	61	..	..	37	..	2
Honomu	..	94	4	..	..	2
Waiakea	..	97	2	..	..	1
Hawi	5	..	24	..	67	4
Hutchinson	..	55	19	..	..	26*
Kaiwiki	..	23	62	4	6	5
Waimanalo	95	1	3	..	..	1
Kohala	1	7	29	21	29	13
Kilauea	7	7	3	50	6	27†
Waianae	100	..	..	..	..	..
Kaeleku	..	100	..	..	..	..
Union Mill	..	5	8	..	87	..
Halawa	..	13	44	..	27	16
Niulii	..	26	37	27	10	..
Waimea	93	..	..	..	..	7
Olowalu	87	..	..	..	..	13
True Average 1928	54.7	20.7	12.9	4.9	2.2	4.6
" " 1927	53.1	23.7	11.8	4.0	1.6	5.8
" " 1926	48.7	25.6	12.1	4.5	2.1	7.0
" " 1925	42.7	30.7	11.9	2.7	2.1	9.9
" " 1924	38.1	32.6	12.0	2.3	2.0	13.0
" " 1923	30.7	36.3	11.2	1.2	1.6	19.0
" " 1922	21.1	40.3	12.2	2.7	1.6	22.1
" " 1921	15.0	45.1	11.0	1.2	1.8	25.9
" " 1920	9.1	42.7	10.0	1.4	2.1	34.7
" " 1919	6.8	46.4	7.2	0.3	2.6	36.7
" " 1918	4.0	42.9	7.5	0.5	1.5	43.6

* Rose Bamboo.
† Principally Badila.

MINOR VARIETIES

One Per Cent or More of the Crop at Any Factory

Variety	1924	1925	1926	1927	1928
Lahaina	...	...	...	...	.63
Striped Mexican	...	...	...	...	.58
Uba	.03	.11	.10	.13	.51
Rose Bamboo	...	...	...	.32	.40
Badila	.46	.35	.47	.37	.27
H 456	...	.11	...	.21	.14
Kohala Seedlings	...	...	.07	.08	.13
Wailuku Seedlings	...	...	.02	.07	.08
U. D. 1	...	...	...	.32	.07
D 117	.49	.52	.15	.25	.05
McBryde 1	...	...	...	...	.02
H 349	...	...	...	...	.01

Lahaina and Striped Mexican, as before noted, now appear in this tabulation. H 20, H 146, and Yellow Bamboo have been dropped, and McBryde 1 together with H 349 have been added.

Uba cane has increased from .13 per cent in 1927 to .51 per cent this year. Rose Bamboo, Kohala Seedlings, and Wailuku Seedlings have also shown an increase, while Badila, H 456, U. D. 1, and D 117 have declined.

Quality of Cane

Table 2 shows data on the quality of cane for the islands as a group, and for the separate islands for the past ten crops. The quality ratio, or the tons of cane to make a ton of sugar, has improved .2 of a ton since 1927. The quality ratio is still the poorest figure shown the past ten years with the exception of last year.

The quality of cane by islands ranks in the usual order, Maui, the best, followed by Oahu, Kauai and Hawaii.

The polarization of the cane has increased .23, and the first expressed juice purity .56 over 1927. The fiber has remained practically the same in the general average.

Considering the changes in the separate islands it is found that the polarization has increased in each; also that the purity has increased except for Kauai, where there was a slight decline. The quality ratio improved in each instance except that for Kauai, which remained the same. The fiber changes have been small except for a .58 per cent increase on Maui. Maui has always been consistently lower in fiber than the other islands until this year. It is still somewhat below that for Hawaii and Kauai.

Tons cane per acre for 1928 and the three previous years, for the five leading varieties, are shown in the following table. The figures are obtained by combining data from the Acreage Census and the Annual Synopsis. A few discrepancies between the two sets of figures may detract slightly from the strict accuracy of these figures, but they are probably accurate to within one ton per acre.

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Per cent Fiber..............	13.07	11.74	12.14	12.61	12.49
Purity 1st Expressed Juice...	87.54	88.81	87.00	85.82	87.34
Quality Ratio	8.66	7.25	7.81	8.20	8.05
1920					
Polarization	12.86	15.29	13.75	13.07	13.64
Per cent Fiber..............	13.36	11.39	12.65	12.72	12.64
Purity 1st Expressed Juice...	87.87	88.94	85.40	86.52	87.24
Quality Ratio	8.45	7.08	8.07	8.28	8.00
1921					
Polarization	12.25	14.67	13.72	12.67	13.12
Per cent Fiber..............	13.28	11.82	12.40	13.28	12.80
Purity 1st Expressed Juice...	87.18	87.37	85.46	84.07	86.22
Quality Ratio	8.98	7.51	8.11	8.76	8.41
1922					
Polarization	12.07	13.95	13.61	13.03	12.97
Per cent Fiber..............	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice...	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.19	7.75	8.04	8.36	8.45
1923					
Polarization	12.09	13.61	12.99	12.94	12.78
Per cent Fiber..............	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice...	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.12	7.91	8.50	8.42	8.57
1924					
Polarization	12.44	14.34	13.48	13.34	13.26
Per cent Fiber..............	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice...	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.86	7.58	8.16	8.12	8.25
1925					
Polarization	12.35	14.42	13.52	13.24	13.22
Per cent Fiber..............	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice...	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.92	7.47	8.18	8.21	8.28
1926					
Polarization	12.53	14.66	13.40	13.03	13.24
Per cent Fiber..............	12.90	12.24	12.72	12.46	12.65
Purity 1st Expressed Juice..	87.59	89.03	86.61	86.68	87.45
Quality Ratio	8.80	7.40	8.29	8.39	8.30
1927					
Polarization	11.34	14.00	12.61	12.07	12.32
Per cent Fiber..............	12.84	11.98	12.29	12.65	12.49
Purity 1st Expressed Juice..	86.27	87.85	85.87	85.17	86.28
Quality Ratio	9.81	7.76	8.86	9.19	8.99
1928					
Polarization	11.57	14.13	13.09	12.09	12.55
Per cent Fiber..............	12.58	12.56	12.13	12.82	12.50
Purity 1st Expressed Juice..	86.60	88.76	86.84	85.16	86.84
Quality Ratio	9.62	7.60	8.45	9.19	8.79

TABLE NO. 3

True Averages of All Factories Except Those Using the Petree Process

	1923	1924	1925	1926	1927	1928
Cane—						
Polarization	12.66	13.08	12.99	12.99	12.05	12.30
Fiber	12.91	12.82	12.80	12.71	12.55	12.47
Tons per ton sugar	8.68	8.40	8.45	8.50	9.24	9.03
Bagasse—						
Polarization	1.53	1.52	1.54	1.58	1.50	1.53
Moisture	41.29	41.26	41.25	41.09	41.61	41.36
Fiber	56.48	56.74	56.55	56.64	56.20	56.42
Polarization % cane	0.35	0.34	0.35	0.35	0.33	0.34
Pol. % pol. of cane	2.76	2.63	2.69	2.73	2.77	2.76
Milling loss	2.71	2.68	2.73	2.79	2.66	2.72
Weight % cane	22.84	22.59	22.63	22.44	22.33	22.11
First Expressed Juice—						
Brix	17.99	18.34	18.14	18.24	17.17	17.45
Polarization	15.61	16.07	15.91	15.88	14.74	15.08
Purity	86.77	87.61	87.67	87.05	85.84	86.41
"Java ratio"	81.1	81.4	81.7	81.8	81.7	81.6
Mixed Juice—						
Brix	13.11	13.37	13.44	13.65	12.88	13.04
Polarization	11.00	11.31	11.38	11.48	10.67	10.89
Purity	83.87	84.56	84.67	84.12	82.88	83.47
Weight % cane	111.95	112.66	111.03	110.10	109.71	109.87
Polarization % cane	12.31	12.74	12.64	12.64	11.71	11.96
Extraction	97.24	97.37	97.31	97.27	97.23	97.24
Extraction ratio	0.21	0.21	0.21	0.21	0.22	0.22
Last Expressed Juice—						
Polarization	1.73	1.84	1.90	2.06	1.88	1.94
Purity	68.48	71.73	69.63	68.72	67.76	68.39
Maceration % cane	34.79	35.30	33.66	32.54	32.04	31.99
Syrup—						
Brix	63.33	63.18	63.63	64.21	62.91	63.05
Purity	85.40	86.02	85.95	85.49	84.54	84.86
Increase in purity	1.53	1.46	1.28	1.37	1.66	1.39
Lbs. avail. CaO per ton cane	1.70	1.72	1.56	1.66	1.52	1.46
Press Cake—						
Polarization	2.20	2.16	2.17	2.49	2.22	2.34
Weight % cane	2.45	2.45	2.45	2.63	2.67	2.87
Polarization % cane	0.05	0.05	0.05	0.07	0.06	0.07
Pol. % pol. of cane	0.43	0.40	0.41	0.50	0.49	0.55
Commercial Sugar—						
Polarization	96.88	97.20	97.23	97.29	97.40	97.49
Moisture	0.80	0.73	0.74	0.66	0.64	0.62
Weight % cane	11.53	11.91	11.83	11.77	10.83	11.08
Polarization % cane	11.17	11.58	11.50	11.45	10.55	10.80
Pol. % pol. of cane	88.37	88.76	88.78	88.41	87.96	88.21
Pol. % pol. of juice	90.86	91.16	91.24	90.95	90.45	90.70
Deterioration factor	0.26	0.26	0.27	0.24	0.25	0.25
Final Molasses—						
Weight % cane	2.96	2.83	2.82	2.94	3.02	2.97
Sucrose % cane	0.99	0.97	0.93	0.99	1.01	0.98
Sucrose % pol. of cane	7.79	7.45	7.20	7.63	8.37	8.00
Sucrose % pol. of juice	8.01	7.65	7.40	7.84	8.60	8.22
Gravity solids	88.54	89.08	90.09	89.59	89.43	88.77
Gravity purity	37.68	37.81	36.97	37.62	37.40	37.41
Undetermined Losses—						
Polarization % cane	0.11	0.14	0.16	0.13	0.11	0.11
Pol. % pol. of cane	0.65	0.76	0.92	0.73	0.41	0.48

TONS CANE PER ACRE

	1925	1926	1927	1928
Crop	53.3	54.4	57.5	61.6
H 109	69.4	69.1	73.7	74.5
Yellow Caledonia	44.8	45.0	45.1	52.6
D 1135	49.3	46.4	46.7	55.3
Yellow Tip	41.0	39.8	36.9	42.3
Striped Tip	31.5	37.0	30.6	39.7

All varieties this year show heavier cane yields, not only over 1927, but over the years 1926 and 1925.

Chemical Control

The number of factories reporting sucrose data has been increased by one, so that 31 factories out of 40, representing 87 per cent of the total sugar produced, are now on a sucrose basis.

Table 6, shows gravity solids and sucrose balances for these factories. Sucrose data for the 31 factories are given in Table 7 with true averages for the last three crops.

Final molasses is now weighed at 28 factories, an increase of one. Eight factories measure their molasses for calculating the weight; four neither weigh nor measure molasses.

Mixed juice is weighed at 36 factories, the same number as for several years, while four factories still base their chemical control on juice measurements.

Lime is now reported in pounds available CaO per ton of cane, both in Table 3 and in the large table, thus conforming to the lime figure used in the Weekly Reports.

Data for pH reactions of the hot limed juice, clarified juice and syrup, also for clarified juice turbidity, are given for the second time. Factories reporting at least partial pH reaction data now number 35, as compared with 30 last year. Turbidity is reported from 24, or one more factory than previously. The pH of the heated mixed juice is averaged for the first time. Last year a number of factories reported pH of cold mixed juice, so that a representative average could not be made.

Apparent and true boiling house recoveries are again given in Tables 4 and 5. As noted last year, true sucrose figures in Table 5 should be considered of the greater significance when factories are listed in both tables. The trend toward higher recoveries, maintained for several years, remains unbroken. There are but 3 factories reporting under 97 per cent of available in Table 4, and only 2 in Table 5. There has been an increase of 3 factories reporting 100 per cent or more on available in Table 4, making a total of 26. Ten report over 101 per cent, against 9 last year. In Table 5, 13 factories are over 100 per cent, and 2 over 101 per cent. The decreasing number of factories with low recoveries is in many instances due to better boiling house supervision and control.

The slight discrepancies in our control methods, resulting in the calculated figure for available sucrose being less than the true theoretical figure for available, have been discussed at length in previous Synopses. While these discrepancies can account for recoveries on available slightly in excess of 100 per cent, it would seem that figures in Table 5, higher than 101 per cent, indicate errors in the con-

TABLE NO. 4

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent polarization actually obtained.

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical†
H. C. & S. Co.	93.27	94.76	101.6	88.7
Oahu	91.75	93.27	101.7	76.8
Ewa	91.87	92.29	100.5	85.9
Waialua	90.90	90.73	99.8	85.7
Maui Agr.	93.23	94.39	101.2	100.5
Pioneer	91.93	92.65	100.8	90.0
Olaa	91.19	89.65	98.3	97.6
Haw. Sug.	92.95	93.98	101.1	91.1
Lihue	89.61	90.80	101.3	78.0
Honolulu	90.80	87.43	96.3	95.8
Onomea	91.42	91.88	100.5	89.6
Hilo	91.37	92.38	101.1	86.7
Kekaha	90.11	90.12	100.0	91.2
Haw. Agr.	90.42	90.34	99.9	90.3
Wailuku	91.90	92.41	100.6	95.2
Hakalau	91.67	92.59	101.0	89.2
Makee	86.71	87.86	101.3	83.7
Honokaa	89.06	89.89	100.9	91.7
McBryde	91.94	92.54	100.7	88.2
Laupahoehoe	93.72	93.01	99.2	84.4
Kahuku	89.95	93.02	103.4	92.3
Hamakua	92.27	92.82	100.6	81.5
Pepeekeo	92.26	93.05	100.9	88.1
Paauhau	90.05	89.54	99.4	92.7
Koloa	89.22	90.61	101.6	92.7
Honomu	92.08	92.67	100.6	93.4
Waiakea	89.32	87.80	98.3	86.3
Hawi	88.09	87.52	99.4	91.0
Hutchinson	90.67	90.14	99.4	92.9
Kaiwiki	90.61	90.90	100.3	92.0
Waimanalo	90.30	90.45	100.2	89.2
Kohala	91.14	91.52	100.4	91.4
Kilauea	84.07	83.79	99.7	86.2
Waianae	90.16	88.21	97.8	87.1
Kaeleku	86.54	85.86	99.2	81.7
Union Mill	89.61	90.15	100.6	....
Halawa	89.90	90.33	100.5	....
Niulii	86.13	88.38	102.6	....
Waimea	91.23	85.67	93.9	....
Olowalu	89.62	81.77	91.2	71.6

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained	% Recovery on Available	Molasses Produced on Theoretical*
H. C. & S. Co.	93.27	94.27	101.1	83.7
Oahu	91.88	92.34	100.5	73.6
Ewa	91.94	91.58	99.6	86.6
Waialua	90.97	89.33	98.2	87.7
Maui Agr.	93.46	93.64	100.2	100.7
Pioneer	92.00	91.78	99.8	89.8
Haw. Sug.	93.02	93.08	100.1	88.7
Lihue	89.94	89.43	99.4	77.9
Honolulu	91.05	86.28	94.8	113.9
Onomea	91.46	91.55	100.1	90.3
Hilo	91.13	92.04	101.0	82.6
Haw. Agr.	90.63	89.44	98.7	96.7
Wailuku	92.01	91.68	99.6	95.9
Hakalau	91.82	91.89	100.1	89.1
Makee	86.86	86.70	99.8	82.3
Honokaa	89.06	89.32	100.3	90.4
McBryde	92.06	91.68	99.6	89.0
Laupahoehoe	93.53	92.57	99.0	87.6
Kahuku	90.13	91.63	101.7	84.9
Hamakua	92.25	92.38	100.1	82.6
Pepeekeo	92.51	92.77	100.3	90.1
Paauhau	90.00	89.01	98.9	95.6
Koloa	89.39	89.63	100.3	91.0
Honomu	92.10	92.16	100.1	92.0
Waiakea	89.63	87.04	97.1	95.4
Hutchinson	90.61	89.72	99.0	96.3
Waimanalo	90.19	89.94	99.7	88.1
Kohala	91.37	91.05	99.7	94.0
Kilauea	84.30	82.82	98.2	87.0
Waianae	90.26	87.66	97.1	94.4
Olowalu	89.28	81.46	91.2	90.2

* Calculated by the S. J. M. formula.

TABLE NO. 6

GRAVITY SOLIDS AND SUCROSE BALANCES

Factory	Gravity Solids per 100 Gravity Solids in Mixed Juice				Sucrose per 100 Sucrose in Mixed Juice			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	...	85.2	13.1	1.7	...	94.27	5.63	0.10
Oahu	6.0	76.9	13.0	4.1	0.85	91.56	5.97	1.62
Ewa	5.7	75.3	16.3	2.7	0.54	91.09	6.98	1.39
Waialua	4.3	75.0	17.0	3.7	0.47	88.91	7.92	2.70
Maui Agr.	...	84.1	16.0	—0.1	...	93.64	6.58	—0.22
Pioneer	4.4	76.7	16.9	2.0	0.32	91.49	7.18	1.01
Haw. Sug	4.3	79.8	14.3	1.6	0.76	92.37	6.19	0.68
Lihue	4.3	72.6	17.8	5.3	0.51	88.97	7.84	2.68
Honolulu	4.3	72.5	22.0	1.2	0.52	85.83	10.19	3.46
Onomea	4.4	75.8	18.0	1.8	0.14	91.42	7.72	0.72
Hilo	5.2	76.7	15.7	2.4	0.41	91.66	7.32	0.61
Haw. Agr.	3.4	75.7	18.8	2.1	0.41	89.07	8.82	1.70
Wailuku	4.7	78.0	16.4	0.9	0.44	91.28	7.65	0.63
Hakalau	3.7	77.0	17.3	2.0	0.15	91.75	7.28	0.82
Makee	4.1	69.0	22.1	4.8	0.44	86.32	10.81	2.43
Honokaa	6.3	70.9	20.9	1.9	0.64	88.75	9.89	0.72
McBryde	3.3	77.4	16.9	2.4	0.41	91.30	7.06	1.23
Laupahoehoe	4.1	79.4	13.8	2.7	0.17	92.41	5.66	1.76
Kahuku	6.0	72.5	19.4	2.1	0.81	90.89	8.37	—0.07
Hamakua	...	81.1	15.4	3.5	...	92.38	6.40	1.22
Pepeekeo	5.3	76.8	16.4	1.5	0.17	92.61	6.76	0.46
Paauhau	4.5	74.3	19.6	1.6	0.47	88.59	9.56	1.38
Koloa	5.8	70.6	21.7	1.9	0.55	89.14	9.66	0.65
Honomu	5.2	76.9	16.6	1.3	0.20	91.98	7.27	0.55
Waiakea	6.0	72.1	19.0	2.9	0.98	86.19	9.89	2.94
Hutchinson	7.3	72.2	19.1	1.4	0.43	89.33	9.04	1.20
Waimanalo	5.5	73.5	18.4	2.6	0.39	89.59	8.64	1.38
Kohala	5.3	76.1	17.4	1.2	0.86	90.27	8.11	0.76
Kilauea	4.0	63.1	28.0	4.9	1.41	81.65	13.66	3.28
Waianae	4.5	72.4	20.0	3.1	1.01	86.77	9.19	3.03
Olowalu	5.7	65.4	20.5	8.4	0.30	81.22	9.67	8.81

TABLE NO. 7
SUCROSE DATA

Factory	Cane Sucrose*	MIXED JUICE		SYRUP		SUGAR		Undetermined Loss per 100 Sucrose* in cane
		Sucrose	Gravity Purity	Gravity Purity	Increase in Purity	Sucrose	Sucrose per 100 Sucrose* in cane	
H. C. & S. Co.	15.02	12.95	89.06†	89.07	0.01	97.98	91.78	0.10
Oahu	13.50	12.07	86.46	87.57	1.11	98.37	89.68	1.59
Ewa	13.10	11.14	84.08	86.00	1.92	98.12	89.32	1.37
Waialua	13.64	11.61	85.65	86.5	0.85	97.99	86.46	2.62
Maui Agr.	14.28	12.52	88.36†	88.53	0.17	97.79	91.30	—0.21
Pioneer	14.08	12.87	85.01	86.06	1.05	98.01	89.04	0.98
Haw. Sug.	14.39	13.13	87.36	88.43	1.07	98.18	90.10	0.67
Lihue	11.68	10.56	82.44	83.3	0.86	97.50	86.78	2.61
Honolulu	13.69	11.81	86.71	87.8	1.09	100.00	83.15	3.36
Onomea	11.07	9.55	84.14	85.26	1.12	97.77	90.13	0.71
Hilo	11.48	10.06	85.47	86.49	1.02	97.69	89.87	0.59
Haw. Agr.	11.78	11.44	85.37	86.32	0.95	97.95	86.71	1.66
Wailuku	13.60	11.00	86.75	87.9	1.15	97.78	89.68	0.63
Hakalau	11.39	9.74	84.70	85.47	0.77	97.33	90.53	0.81
Makee	11.05	9.97	81.32	81.7	0.38	97.46	82.13	2.31
Honokaa	10.07	9.39	82.01	83.53	1.52	98.08	84.58	0.69
McBryde	12.92	11.06	85.27	85.79	0.52	97.68	88.29	1.19
Laupahoehoe	12.29	10.34	86.90	88.12	1.22	97.72	89.71	1.71
Kahuku	11.55	9.87	81.63	82.84	1.21	97.90	88.73	—0.07
Hamakua	12.29	12.24	86.13†	86.45	0.32	97.47	89.83	1.18
Pepeekeo	11.97	11.01	84.04	86.20	2.16	98.18	90.45	0.45
Paauhau	11.28	9.64	84.34	85.55	1.21	97.23	86.39	1.35
Koloa	10.88	9.75	80.58	82.4	1.82	97.92	86.37	0.63
Honomu	12.04	10.14	84.57	86.8	2.23	98.21	90.29	0.53
Waiakea	11.90	11.72	84.32	86.48	2.16	97.28	82.45	2.81
Hutchinson	12.18	11.90	83.98	85.11	1.13	97.42	86.52	1.16
Waimanalo	11.92	9.91	82.52	84.72	2.20	97.25	88.46	1.31
Kohala	12.25	9.78	85.04	86.68	1.64	97.43	87.89	0.74
Kilauea	9.96	9.28	77.99	77.96	—0.03	97.41	78.62	3.16
Waianae	14.05	11.75	83.75	84.87	1.12	97.30	84.21	2.89
Olowalu	13.57	11.32	81.81	83.26	1.45	96.95	79.24	8.60
‡True Average 1928	12.69	11.22	85.15	86.23	1.08	97.86	88.49	1.21
" " 1927	12.46	11.01	84.53	85.86	1.33	97.79	87.96	1.13
" " 1926	13.35	11.68	85.38	86.66	1.28	97.67	88.41	1.20

* Polarization in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane.
† Clarified juice.
‡ Refinery data from Honolulu not included in averages.

trol, and that there is the same indication in Table 4, though not to such a positive degree.

Molasses produced on the theoretical is shown in both Tables 4 and 5. The calculation in Table 4 is based on the theoretical being the difference between the gravity solids in the syrup and in the sugar produced. In Table 5, the S. J. M. formula is used. There should be comparatively little difference in the two sets of figures, if there are no discrepancies in the control data, hence their value in checking the control.

It is quite obvious that the factors which depress the calculated available sucrose, increase the figure for the calculated theoretical molasses to a considerably greater extent. The average molasses produced on theoretical in Table 4 for the past six crops has fluctuated between a minimum of 88.6, this year's figure, and a maximum of 91.2 in 1927. The six crops' average is 90.2. While conditions at certain factories may cause more or less variation from the theoretical, a difference of over 5 on either side of the six-year average would indicate, for the factories that are high, errors in control, and for those that are low, control errors, undetermined loss of solids, or both. There are 3 factories over this limit and 7 below.

Table 6 shows gravity solids and sucrose balances for the 31 factories reporting available data. One factory has a negative undetermined loss of solids, and two factories report a negative undetermined loss of sucrose. Both these items indicate error in chemical control. Of the eight factories showing a negative undetermined loss on a polarization basis in the first large table, only the two factories noted above with negative undetermined sucrose have a negative undetermined polarization above one per cent.

Milling

Changes in milling machinery since last year include knives and a new three-roller crusher at Hutchinson factory in place of an old two-roller crusher, and knives at Hawaiian Agricultural Company. A good increase in extraction for both factories is reported. Makee temporarily dispensed with their shredder during the crop just harvested, but this will be restored to use the coming year.

Below is given data pertinent to milling for the past eight seasons:

Year	Tons cane per hour	Tonnage ratio	Tonnage fiber ratio	Tons pressure per linear ft. roller	Maceration per cent cane	Milling loss	Extraction ratio	Extraction
1921	36.58	1.40	17.9	....	39.30	2.64	.20	97.43
1922	39.93	1.54	19.9	65.2	34.75	3.02	.23	96.98
1923	42.03	1.56	20.0	66.2	35.12	2.76	.22	97.23
1924	43.63	1.62	20.6	66.9	34.90	2.78	.21	97.33
1925	45.31	1.71	21.8	66.5	33.63	2.82	.21	97.29
1926	46.43	1.78	22.5	67.4	33.61	2.88	.22	97.25
1927	47.87	1.78	22.2	68.2	32.53	2.73	.22	97.23
1928	49.30	1.83	22.9	70.5	32.16	2.75	.21	97.26

It will be noted that the trend toward increased rate per hour, tonnage ratio and tonnage fiber ratio has remained unbroken, except for a temporary hesitancy in the tonnage ratio and a slight reversal in tonnage fiber ratio last year. The roller pressures have increased each year except in 1925. The maceration percentage has been distinctly downward for the past ten years. Fiber in cane, though not shown above, has had a downward tendency since reaching the high figure of 12.95 in 1922.

Milling efficiency, as evidenced by milling loss, extraction ratio, and extraction, gained rapidly during the years prior to those shown in the above table. These figures reached their peak for all time in 1920 and 1921, with 2.64 milling loss in 1921, .20 extraction ratio in 1920 and 1921, and 97.45 extraction in 1920. Since then the fluctuations shown above have occurred. Higher grinding rates and lower maceration, notwithstanding increased pressures, have decreased milling efficiency about .1 in milling loss, .01 in extraction ratio, and .2 in extraction.

The average maceration this year is 32.16, the lowest figure for sixteen years. All factories reporting 98 extraction or over, 7 in number, show approximately 35 to 40 per cent maceration. In many factories lower maceration has been necessary because of their increased grinding rate with no accompanying increase in evaporative capacity. The question arises as to how much lower maceration can be reduced without having a marked effect on milling results. We know that the present efficiency of maceration is low, and that it is a promising field for study and improvement. There is some evidence that improvements of a practical nature are being developed.

In comparing this year's milling results with those of last year, it is found that there has been a small improvement in extraction and extraction ratio accompanied by a 3 per cent increase in grinding rate with a like increase in tonnage fiber ratio. The milling loss is slightly poorer, and maceration per cent cane has decreased. Bagasse moisture is .30 lower, and the polarization .02 higher. Twenty-four factories report increased extraction with 15 reporting a decrease and one with no change.

Data for non-Petree process factories show a slight reduction in the difference between first expressed juice purity and mixed juice purity, 2.94 against 2.96. Any reduction is a hopeful sign of either cleaner mill conditions, less cane trash, or both.

Table 8 shows the factories listed in the order of their milling loss, with other milling data in the same form as the past two years. Hakalau and Onomea have been passed by Waimanalo. Hilo and Honomu retain their same relative positions. Hawi has jumped from 21st to 6th position. In 1926 this factory was number 32 in the list. The factories that have also materially bettered their positions are Hutchinson, Maui Agricultural Co., Hawaiian Agricultural Co. and Kohala, in the order named. Those that show a position considerably lower than last year are Waialua, Pioneer, Kekaha, Honolulu, McBryde and Waimea.

TABLE NO. 8—MILLING RESULTS

Showing the Rank of the Factories on the Basis of Milling Loss.

Rank	1927 Rank	Factory	Milling Loss	Extraction Ratio	Extraction	Maceration	Tonnage Ratio	Tonnage Fiber Ratio*
1	3	Waimanalo....	1.16	0.10	98.67	40.18	1.97	26.44
2	1	Hakalau.......	1.23	0.11	98.65	36.09	1.74	21.40
3	2	Onomea.......	1.29	0.12	98.57	34.97	1.96	23.85
4	4	Hilo..........	1.65	0.14	98.03	34.98	1.81	24.65
5	5	Honomu.......	1.82	0.15	98.15	37.57	1.51	18.32
6	21	Hawi.........	2.02	0.16	97.84	32.71	1.72	22.69
7	8	Wailuku.......	2.03	0.15	98.23	40.91	1.27	14.87
8	11	Paauhau.......	2.14	0.19	97.50	36.50	1.10	14.37
9	6	Kahuku.......	2.16	0.19	97.58	35.82	1.57	20.10
10	7	Ewa..........	2.17	0.17	98.04	36.68	1.76	20.63
11	14	Lihue.........	2.18	0.19	97.49	31.79	2.19	28.78
12	12	Pepeekeo......	2.23	0.19	97.66	27.22	1.85	23.05
13	15	Oahu..........	2.26	0.17	97.92	31.20	1.91	23.47
14	10	Olowalu.......	2.41	0.18	97.55	39.21	1.55	21.05
15	9	Kekaha........	2.42	0.19	97.87	27.55	1.85	21.22
16	13	Hamakua......	2.57	0.22	97.20	21.39	1.40	18.63
17	19	Koloa.........	2.59	0.24	96.85	30.67	1.42	18.55
18	27	Haw. Agr.....	2.67	0.23	97.32	20.33	1.96	22.87
19	24	Kohala........	2.73	0.23	97.34	42.40	1.63	19.10
20	17	Kilauea.......	2.77	0.28	96.24	27.33	1.53	20.38
21	22	Haw. Sug.....	2.78	0.20	97.52	28.96	1.63	20.72
22	32	Maui Agr.....	2.84	0.20	97.48	34.13	2.00	25.00
23	20	Laupahoehoe...	2.85	0.23	97.05	36.95	1.68	21.17
24	37	Hutchinson....	3.01	0.25	96.83	21.12	1.96	25.03
25	18	Pioneer.......	3.02	0.22	97.28	30.51	2.20	27.50
26	28	H. C. & S. Co..	3.11	0.21	97.35	35.75	1.82	23.11
27	16	Waialua.......	3.17	0.24	96.96	37.71	2.50	32.00
28	23	McBryde......	3.19	0.25	96.68	36.62	1.42	18.94
29	26	Olaa..........	3.25	0.27	96.83	29.23	2.33	27.61
30	25	Waimea.......	3.31	0.25	96.91	38.00	1.48	18.34
31	30	Waianae.......	3.65	0.26	96.97	36.42	1.53	17.64
32	35	Waiakea.......	3.74	0.32	95.61	22.68	1.60	22.06
33	31	Honokaa......	3.74	0.38	95.26	26.11	1.66	20.93
34	29	Honolulu......	3.90	0.29	96.84	32.02	1.82	19.89
35	34	Kaiwiki.......	3.91	0.31	96.16	31.77	1.71	20.95
36	33	Makee........	4.06	0.37	95.06	29.55	2.17	28.75
37	36	Kaeleku.......	4.07	0.36	94.91	30.48	1.89	26.67
38	38	Niulii.........	4.39	0.42	94.24	26.73	1.88	25.79
39	40	Halawa........	5.12	0.44	93.82	28.76	1.67	23.33
40	39	Union Mill....	5.56	0.48	93.50	22.91	1.72	23.19

* Tonnage ratio multiplied by per cent fiber in cane.

Boiling House Work

Clarification: The averages in Table 3, for non-Petree process factories show that the increase in purity from mixed juice to syrup is .27 less than last year. This is influenced slightly by the higher purity of the first expressed juice this year. Twenty-three factories report a smaller increase, 16 a larger figure, and 1 no change. The purity increase figure now stands at 1.39, and in the light of clarification investigations carried on for several years by this Station, it appears far lower than that obtainable when the mixed juice is limed to the point recommended for the best increase. The importance of purity increase is apparent when it is realized that there is additional recovery that is practically equal to the purity increase. We have this year pH figures for limed mixed juice from 28 factories, and 18 show reactions below the range that experimental work has indicated the maximum increase in purity is secured. There are 6 factories not reporting any pH data, and the average purity increase is only .91 for these factories, compared with 1.39 for all non-Petree factories.

The figure for lime per ton of cane is less than last year, indicating, though not positively, that the juice has been limed on the whole to a lower reaction.

Liming at a number of factories is carried at a moderate reaction because of inadequate filter press equipment. The volume of settlings is reduced by reducing the amount of lime used in clarification, and with the increased rate of grinding without additional increase in filtration equipment, the situation becomes more acute.

The turbidity of clarified juice as reported by the 24 factories that are regularly making these tests is 3.46 this year, compared with 3.59 last year. As the individual factories reporting turbidity for the two years are practically identical, the two figures are comparable, thus showing a more turbid juice this year for these factories. Several factories are becoming decidedly under capacity in settling equipment. Experimental work has shown that underliming produces less clear juices. The work has also shown that poor clarification is one of the factors affecting the filtration rate of sugars.

The smaller increase of purity in clarification has shown its influence on the difference between first expressed juice and syrup, this having increased .17 this year. The figures for the last seven crops are tabulated below:

Year	Purity difference first expressed juice to syrup
1922	1.88
1923	1.40
1924	1.54
1925	1.65
1926	1.67
1927	1.41
1928	1.58

Filter Presses: As shown by data in Table 3, it is found that the filter press work is less satisfactory than last year. The cake polarization has increased from 2.22 to 2.34, the amount of cake per cent cane from 2.67 to 2.87, and the loss per cent polarization of cane from .49 to .55. The weight and loss are the largest crop figures that have been reported.

As a result of faster grinding a number of factories allowed more cush-cush to pass into the mixed juice to improve the filtration characteristics of the settlings, thus increasing filter capacity. Faster grinding can account for the larger loss.

The Oliver filtration equipment at Oahu has been increased the past year, though not to the point that these filters have handled all the settlings. One Oliver unit was in use this year at Olaa. These filters are giving satisfactory service.

Evaporation: With faster grinding and very little, if any, change in evaporator equipment, the syrup has dropped but little in density this year. The syrup density was at its highest figure on record, 64.04 Brix in 1926. In 1927, there was a drop to 63.10; this year it is 63.04. The equipment is being operated at higher capacity each year. The percentage increase of evaporation per hour from year to year is as follows: 1925, 2.6; 1926, 2.6; 1927, 3.2; and 2.3 per cent in 1928.

Commercial Sugar: The polarization of sugar has increased .11, or to 97.51. The only previous year that this figure has been exceeded was 97.55 in 1911. After 1911 there was a decline in polarization to a low figure of 96.3 in 1916. In 1919 the polarization was 96.34, since which time there has been a yearly increase to the present average of 97.51.

The average increase in polarization this year is again brought about by an increase in polarization by the group of factories shipping to the Crockett refinery. There has been a further decline in the average polarization of Western refinery factories. The polarization spread between the two factory groups is .79, the averages being 97.70 for Crockett and 96.91 for Western.

The moisture in sugar is again somewhat lower than the previous year, .62 as compared with .65. The deterioration factor is down to a new low figure, .249. While the average is below the limit of .250 recommended for safety from deterioration, it means that there is still a large proportion of the sugar above this figure subject to polarization loss if the sugar is stored for any extended length of time.

The grain of the sugar has been better this year than for several years. Seventy-two per cent of the factories reduced the amount of small grain. The average filtration rate of the sugar shipped to Crockett refinery up to the end of October, had increased 1.8, or to 80.9. The maximum rate was 81.5 in 1926.

The amount of sour sugar is less than previously reported for any crop, though the amount of hard sugar has increased. The quality of commercial sugar is further discussed in the Raw Sugar Technical Committee Report.

Low Grades: The gravity purity of final molasses is again lower than that for the previous year, standing at 37.39 as compared with 37.59 for 1927, and 37.97 in 1926. The record low purity was 37.32 in 1925. Twenty-one factories report lower gravity purity than last year, and 16 show a higher figure. No factory has equalled the low record purity of 31.81 made by Kahuku last year. Two factories, Laupahoehoe and Waianae, have installed crystallizers in place of cooling tanks. The decreases in molasses gravity purity from the year before were 6.87 and 5.70 respectively. Hamakua and Hutchinson have had crystallizers for two crops, or slightly less, and their decreased purity since two years ago is 6.98

TABLE NO. 9

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

		Recovery % Calculated Recovery *			Recovery % Recovery Indicated by "Sugar Ratio" †	
Rank	Factory	Milling	Boiling House	Over All	Rank	Over All
—	Kahuku	97.58	104.62	102.49	—	101.10
1	Hakalau	98.65	102.02	100.87	1	100.59
2	Onomea	98.57	101.44	100.27	2	100.30
3	Pepeekeo	97.66	102.22	99.98	3	99.89
—	Lihue	97.49	101.99	99.93	—	99.10
—	Koloa	96.85	102.62	99.85	—	98.92
—	Maui Agr	97.48	101.61	99.48	—	99.71
4	Honomu	98.15	100.97	99.39	4	99.39
5	Ewa	98.04	100.95	99.28	5	99.28
—	H. C. & S. Co	97.35	101.38	99.06	—	99.53
6	Pioneer	97.28	101.43	99.03	7	98.60
7	Hamakua	97.20	101.25	98.86	11	97.79
—	Oahu	97.92	100.49	98.68	—	99.32
—	Hilo	98.03	100.28	98.58	—	99.18
8	Waimanalo	98.67	99.62	98.54	6	98.73
9	McBryde	96.68	101.38	98.30	8	98.27
—	Haw. Sug	97.52	100.51	98.22	—	98.72
10	Wailuku	98.23	99.45	97.95	12	97.43
11	Kekaha	97.87	99.52	97.93	9	97.80
12	Laupahoehoe	97.05	99.88	97.22	9	97.80
13	Kohala	97.34	99.09	96.76	13	97.41
14	Haw. Agr	97.32	98.71	96.27	14	96.59
15	Waialua	96.96	98.85	96.25	16	96.39
16	Hawi	97.84	97.92	96.19	18	95.48
17	Hutchinson	96.83	98.99	96.16	17	95.99
18	Honokaa	95.26	100.45	96.12	19	95.32
—	Makee	95.06	100.22	95.89	—	93.20
19	Paauhau	97.50	97.83	95.69	15	96.40
20	Kilauea	96.24	98.65	95.57	22	93.68
21	Kaiwiki	96.16	98.23	94.77	20	95.14
22	Waianae	96.97	96.74	94.13	23	93.45
23	Olaa	96.83	96.85	94.06	21	94.48
—	Niulii	94.24	98.53	93.39	—	91.76
24	Halawa	93.82	98.24	92.59	25	93.22
25	Honolulu	96.84	95.13	92.45	24	93.39
26	Kaeleku	94.91	96.55	92.06	28	91.13
27	Waiakea	95.61	95.07	91.23	27	91.32
28	Union Mill	93.50	97.06	91.13	26	91.59
29	Waimea	96.91	93.29	90.64	29	90.89
30	Olowalu	97.55	91.17	89.31	30	87.56

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses. Factories reporting boiling house recovery in excess of 101% on available (Table 4) are included in the table but no ranking is assigned.

† The basis of this calculation is 98.02 extraction, syrup purity one less than the apparent purity of the first expressed juice, gravity purity of molasses 33.33 and no other losses. In this case also no rank has been assigned when over 101% boiling house recovery on available has been reported.

and 3.65 respectively. Other factories that show a marked decrease in molasses purity this year are McBryde, H. C. & S. Co., Maui Agricultural Co., and Kaeleku. There are five factories at which the gravity purity of the molasses has increased 1.0 or more since 1927.

Undetermined Loss: The undetermined polarization loss as shown on the large table remains at .32, the same as in 1927. For the 31 factories on a sucrose basis the loss has increased .08 to 1.21, or about the same as for 1926. At many of the factories these loss figures fluctuate widely from year to year, so that it is hard to draw conclusions from small changes in the averages. It can be said, however, that since higher liming went into practice in 1922 and 1923, there has been more than 1 per cent reduction in the undetermined loss.

Recovery

Boiling house recovery has increased from 90.76 to 91.24, and recovery per cent polarization in cane from 88.25 to 88.76, or .48 and .50 respectively.

Factors tending toward higher recovery this year are, higher extraction, higher initial purities, lower purity final molasses, and the smaller decrease in purity from first expressed to mixed juice. Those that tend toward lower recovery are, the smaller purity increase in clarification, larger press loss, and higher sugar polarization. The higher polarization tends to decrease the recovery .05. As higher sugar polarization does not decrease the recovery of available sugar it can be considered that the recovery has increased .55. Calculations based on normal juice indicate that with the better initial purity the recovery should have increased .58. To this would be added .03 for better extraction, and .10 for lower molasses purity. However, the poorer work in clarification, and higher filter press loss decrease the figure .21 and .05 respectively. We thus have a net indicated gain over last year of .45, compared with an actual gain of .55, reflecting slightly better boiling house efficiency.

The 1928 year's results show that we have had a better quality cane, have slightly increased mill extraction, and improved in our low grade work. Our undetermined losses are low. The results in clarification and filter press work are somewhat poorer, but this can be attributed to the increased grinding rate, with very little provision made toward strengthening these stations in the factories that are distinctly under capacity.

Comparison of Actual and Calculated Recoveries

Table 9 shows the comparisons and ranking of the factories in the same form as last year. Factories with over 101 per cent of the theoretical boiling house recovery in Table 4 are included but not given a ranking number. Several factories have materially bettered their standing.

As expressed in previous Synopses, these calculations are of value in obtaining an approximate idea of the quality of the work in the various factories, but drawing close distinctions is not justified. If very close comparisons are to be made they would have to be based on an analysis of all available control data.

The summary of losses is given in the usual form in Table 10.

The calculations in this Synopsis have been made by A. Brodie with the assistance of others in this department.

ANNUAL SYNOPSIS OF MILL DATA--SHOWING RESULTS FROM 40 HAWAIIAN FACTORIES FOR CROP OF 1928

Factory	Factory No.	Milling Plant (Sizes in Inches)	CANE: Polarization	CANE: % Fiber	CANE: Tons per ton commercial sugar	CANE: Tons ground per hour	CANE: Tonnage ratio
H. C. & S. Co.**	6	K(4),2RC78(2),S72(2),12RM78(2)	14.91	12.70	7.11	64.00‡	1.82
Oahu	20	K(2),2RC78(2),S72(2),12RM78(2)	13.34	12.29	8.13	67.20‡	1.91
Ewa	5	K(2),2RC78,18RM78	12.95	11.72	8.38	86.95	1.76
Waialua	17	K(2),2RC78,12RM78	13.39	12.80	8.33	88.18	2.50
Maui Agr.**	21	K(4),3RC66(2),12RM66(2)	14.12	12.50	7.50	50.43‡	2.00
Pioneer	10	K,2RC72,S72,15RM72	13.92	12.50	7.82	79.08	2.20
Olaa	36	K,S72,12RM78	12.20	11.85	9.28	65.55	2.33
Haw. Sug.	16	K,2RC72,S72,12RM78	14.22	12.71	7.57	57.55	1.63
Lihue	27	K,2RC78,S72,12RM78	11.46	13.14	9.62	77.69	2.19
Honolulu	13	K(2),S54,2RC78,9RM78	13.51	10.93	8.79	51.40	1.82
Onomea	34	2RC60,S54,12RM66	10.99	12.17	9.80	49.28	1.96
Hilo	33	K,2RC66,12RM66	11.40	13.62	9.47	45.57	1.81
Kekaha	25	2RC54,15RM60	13.05	11.47	8.54	46.31	1.85
Haw. Agr.††	30	K,3RC60,12RM66	11.64	11.67	9.59	49.35	1.96
Wailuku	2	K,2RC72,12RM78	13.43	11.71	8.01	44.62	1.27
Hakalau	7	2RC54,12RM9-60,3 66	11.22	12.30	9.44	36.27	1.74
Makee††	14	K,2RC72,9RM72	10.87	13.25	10.74	52.17	2.17
Honokaa††	35	K(2),2RC66,12RM66	9.97	12.61	11.52	41.72	1.66
McBryde	12	K,2RC72,S72,9RM84	12.77	13.34	8.56	46.13	1.42
Laupahoehoe	41	K,2RC60,9RM60	12.17	12.60	8.87	27.94	1.68
Kahuku	43	K,2RC60,S54,9RM72	11.37	12.80	9.55	37.78	1.57
Hamakua**	15	K,2RC60,12RM60	12.20	13.31	8.83	29.22	1.40
Pepeekeo	19	2RC54,9RM60	11.87	12.46	9.07	30.80	1.85
Paauhau††	24	2RC60,12RM66	11.15	13.06	9.97	27.78	1.10
Koloa	38	K,2RC60,12RM66	10.74	13.06	10.42	35.72	1.12
Honomu	37	3RC60,9RM60	11.95	12.13	9.03	25.23	1.51
Waiakea	3	K,2RC60,9RM60	11.77	13.79	9.92	26.68	1.60
Hawi	26	K(2),2RC54,12RM54	12.27	13.19	9.24	29.0	1.72
Hutchinson††	31	K,3RC60,9RM60	12.08	12.77	9.24	32.61	1.96
Kaiwiki	32	K,2RC60,9RM60	12.49	12.25	8.97	28.58	1.71
Waimanalo††	1	K,3RC54,9RM54	11.80	13.12	9.22	26.55	1.97
Kohala	40	K(2),3RC60,9RM60	12.14	11.72	9.05	27.21	1.63
Kilauea††	23	K,3RC60,9RM60	9.82	13.32	12.43	25.5	1.53
Waianae	9	K,12RM60	13.90	11.53	8.22	25.45	1.53
Kaeleku	47	K,2RC54,9RM60	11.28	14.11	10.74	31.43	1.89
Union Mill	11	K,9RM60	11.57	13.48	10.00	21.50	1.72
Halawa	29	K,2RC60,6RM50	11.57	13.97	9.99	14.49	1.67
Niulii	39	K,9RM54	10.49	13.72	11.18	19.05	1.88
Waimea	4	2RC48,12RM42	13.26	12.39	8.87	15.15	1.48
Olowalu	18	K,3RC48,9RM48	13.43	13.58	9.02	16.35	1.55
True Averages, 1928			12.55	12.50	8.78	49.30	1.83
" " 1927			12.32	12.49	8.98	47.87	1.78
" " 1926			13.24	12.65	8.31	46.43	1.78
" " 1925			13.22	12.74	8.27	45.31	1.71
" " 1924			13.26	12.74	8.26	43.63	1.62
" " 1923			12.78	12.82	8.56	42.03	1.56
" " 1922			12.97	12.95	8.62	39.93	1.54
" " 1921			13.12	12.80	8.61	36.58	1.40
" " 1920			13.64	12.64	8.12	39.34	....
" " 1919			13.74	12.49	7.94	....	....

* Includes portion 1929 crop.
† Refined sugar.
‡ For one tandem only.
¶ Probably influenced by refinery products.
§ 1928 crop unfinished.
** Petree process.
*† Balance of 1927 crop included.

CANE MILL DATA, SEASON OF 1928

Factory	Factory No.	Milling Plant (Sizes in Inches)	Revolving Knives, First Set: Number	First Set: Distance Apart, Inches	First Set: Distance from Conveyor, Inches	First Set: Revolutions per Minute	Second Set: Number	Second Set: Distance Apart, Inches	Second Set: Distance from Conveyor, Inches	Second Set: Revolutions per Minute	Mill Openings: Crusher	1st Mill Front	1st Mill Back	2nd Mill Front	2nd Mill Back	3rd Mill Front	3rd Mill Back	4th Mill Front	4th Mill Back	5th Mill Front	5th Mill Back
H. C. & S. Co.	6	K(2)-2RC34x78,S72,12RM34x78	28	9 3/4	24	1,200	56	5	16	1,200	1/8	7/16	1/16	5/16	1/32	5/16	0	7/16	0	....	....
" "	6	K(2)-2RC34x78,S72,12RM34x78	28	9 3/4	24	1,200	48	5	16	1,200	1/8	7/16	1/16	5/16	1/32	5/16	0	7/16	0	....	....
Oahu	20	K,2RC34x78,S72,12RM34x78	28	5 1/2	18	400	....	....	....	....	1/8	7/16	0	5/8	0	3/8	0	3/8	0	....	....
"	20	K,2RC34x78,S72,12RM34x78	28	5 1/2	16	600	....	....	....	....	1/8	3/8	0	5/8	0	1/2	0	5/8	0	....	....
Ewa	5	K(2)2RC34x78,18RM34x78	28	2	14	580	72	1	1	580	3/8	1	1/8	3/4	1/8	3/4	1/16	7/8	1/8	1/2	1/16†
Waialua	17	K(2)2RC34x78,12RM34x78	70	1 1/2	14	580	76	1 1/2	2 1/2	580	3/4	1/8	0	1/4	0	1/4	0	1/4	0	....	....
Maui Agr.	21	K,2-3RC34x60,12RM34x60	72	7/8	10	480	72	7/8	7/8	520	7/8x1/4	3/8	0	1/2	0	3/16	0	1/16	0	....	....
"	21	K,2-3RC34x60,12RM34x60	72	7/8	10	480	72	7/8	7/8	520	7/8x1/4	3/8	0	1/2	0	3/16	0	1/16	0	....	....
Pioneer	10	K,2RC34x72,S72,15RM34x72	72	2 1/4	16	400	....	....	....	....	1/8	7/16	1/16	7/16	0	7/16	0	7/16	0	7/16	0
Olaa	36	K,S72,12RM-32x78,3-34x78	36	3 15/16	4 1/2	450	....	....	....	....	....	1 1/8	3/16	11/16	1/8	7/16	0	3/16	0	....	....
Haw. Sug.	16	K,2RC34x72,S72,12RM34x78	30	4	15	450	....	....	....	....	1/4	7/16	1/16	3/8	0	3/8	0	1/4	0	....	....
Lihue	27	K,2RC34x78,S72,12RM34x78	10	7	10	425	....	....	....	....	1/4	11/16	1/8	9/16	0	7/16	0	1/4	0	....	....
Honolulu	13	K(2),S54,2RC34x54,9RM34x78	24	6	10	565	24	6	4	565	1 1/4	5/8	1/8	1/2	1/32	3/8	0	1/4	0	....	....
Onomea	34	2RC28x54,12RM28x60	....	....	....	....	....	....	....	....	1/4	5/8	1/16	3/8	0	1/4	0	1/4	0	....	....
Hilo	33	K,2RC32x60,12RM32x60	24	6	5	400	....	....	....	....	3/8	3/4	1/16	1/4	0	3/16	0	1/2	0	....	....
Kekaha	25	2RC24x54,15RM32x60	....	....	....	....	....	....	....	....	7/8	7/8x1/4	1/4	11/16	3/16	5/8	1/8	1/2	1/16	1/2	1/32
Haw. Agr.	30	K,3RC32x60,12RM32x60	22	2 1/2	....	493	....	....	....	....	5/8x1/2	1/4	1/4	5/8	1/16	5/8	1/16	1/4	0	....	....
Wailuku	2	K,2RC24x72,12RM34x78	10	6	18	400	....	....	....	....	1/8	3/8	0	3/8	0	3/16	0	1/4	0	....	....
Hakalau	7	2RC24x54,12RM30x60,3-32x60	....	....	....	....	....	....	....	....	1/8	3/4	0	3/8	0	1/8	0	1/4	0	....	....
Makee	14	K,3RC34x72,9RM34x72	14	6	30	370	....	....	....	....	3/16	7/16	0	9/32	0	1/4	0	....	....	....	....
Honokaa	35	K(2)2RC30x66,12RM32x66	16	4	14	400	16	4	5	500	5/8	1/2	3/32	3/8	1/16	5/16	1/32	1/4	0	....	....
McBryde	12	K,2RC34x72,S72,9RM34x84	12	8	18	450	....	....	....	....	3/8	1/2	0	7/16	0	13/32	0	....	....	....	....
Laupahoehoe	41	K,2RC30x60,9RM32x60	16	3 3/4	1 1/2	400	....	....	....	....	3/8	5/16	0	3/8	0	3/8	0	....	....	....	....
Kahuku	43	K,2RC30x60,S54,9RM30x72	10	3 1/2	2 1/2	400	....	....	....	....	7/16	5/16	0	3/16	0	1/4	0	....	....	....	....
Hamakua	15	K,3RC30x60,12RM32x60	12	4	2	400	....	....	....	....	1/4	1/2	0	1/4	0	1/8	0	3/16	0	....	....
Pepeekeo	19	2RC24x54,9RM32x60	....	....	....	....	....	....	....	....	1/8	3/4	0	3/16	0	1/8	0	....	....	....	....
Paauhau	24	2RC26x60,12RM32x60	....	....	....	....	....	....	....	....	3/8	5/8	0	1/4	0	3/16	0	....	....	....	....
Kohala	38	K,2RC26x60,12RM32x60	12	4 1/2	8	300	....	....	....	....	1/4	3/4	1/4	1/2	3/16	3/8	1/16	1/4	0	....	....
Honomu	37	3RC30x54,9RM32x60	....	....	....	....	....	....	....	....	3/4x1/16	5/8	0	9/32	0	1/4	0	....	....	....	....
Waiakea	3	K,2RC27x60,9RM32x60	36	3 3/4	4 1/2	385	....	....	....	....	0	1/2	0	3/16	0	1/8	0	....	....	....	....
Hawi	26	K(2)2RC30x54,12RM30x54	22	4	16	570	28	3	3	570	5/8	1/8	1/16	1/4	1/32	1/4	0	1/4	0	....	....
Hutchinson	31	K,3RC32x60,9RM32x60	22	2 1/2	2	500	....	....	....	....	5/8x1/16	5/8	1/32	3/8	1/16	1/4	0	....	....	....	....
Kaiwiki	32	K,2RC24x60,9RM32x60	18	3	2	350	....	....	....	....	1/2	7/16	0	3/16	0	5/16	0	....	....	....	....
Waimanalo	1	K,3RC30x54,9RM30x54	28	1 1/8	3 1/2	400	....	....	....	....	1/2x1/16	3/8	0	1/4	0	1/8	0	....	....	....	....
Kohala	40	K(2),3RC30x60,9RM32x60	12	4	18	375	36	1 1/2	1 1/2	400	5/8x3/16	3/8	0	1/4	0	1/4	0	....	....	....	....
Kilauea	23	K,3RC32x60,9RM32x60	22	2 1/2	2 1/2	400	....	....	....	....	3/8x3/16	3/8	0	3/16	0	1/8	0	....	....	....	....
Waianae	9	K,12RM30x60,3-32x60	36	3	10	400	....	....	....	....	....	7/8	1/4	1/2	0	1/4	0	3/8	0	....	....
Kaeleku	47	K,2RC24x54,9RM32x60	6	3	6	250	....	....	....	....	1/4	1/4	0	1/2	0	1/4	0	....	....	....	....
Union Mill	11	K,9RM30x60	14	4	5	320	....	....	....	....	....	1/2	0	1/4	0	3/16	0	....	....	....	....
Halawa	29	K,2RC30x60,9RM26x60	20	4 1/2	1/2	390	....	....	....	....	1/8	1/4	0	3/16	0	....	....	....	....	....	....
Niulii	39	K,9RM30x54	9	0	3	525	....	....	....	....	....	3/8	1/16	3/16	1/32	1/8	0	....	....	....	....
Waiakea	4	2RC24x48,12RM26x42	....	....	....	....	....	....	....	....	0	1/2	0	7/16	0	1/4	0	1/4	0	....	....
Olowalu	18	K,3RC26x48,9RM27x48	16	3	3	590	....	....	....	....	3/8x0	5/16	0	1/4	0	1/4	0	....	....	....	....

RETURNER BAR — DISTANCE FROM TOP ROLLER—INCHES

Factory No.	Crusher Toe	Crusher Center	Crusher Heel	1st Mill Toe	1st Mill Center	1st Mill Heel	2nd Mill Toe	2nd Mill Center	2nd Mill Heel	3rd Mill Toe	3rd Mill Center	3rd Mill Heel	4th Mill Toe	4th Mill Center	4th Mill Heel	5th Mill Toe	5th Mill Center	5th Mill Heel
6	.....	.....	.....	1 1/4	1 3/4	2 1/4	1 1/4	1 3/4	2 1/4	1 1/4	1 3/4	2 1/4	1 1/4	1 3/4	2 1/4	.....	.....	.....
6	.....	.....	.....	1 1/4	1 3/4	2 1/4	1 1/4	1 3/4	2 1/4	1 1/4	1 3/4	2 1/4	1 1/4	1 3/4	2 1/4	.....	.....	.....
20	.....	.....	.....	1 1/8	1 5/16	1 11/16	7/8	1 3/16	1 3/8	1 1/8	1 1/4	1 1/2	1	1 1/8	1 1/2	.....	.....	.....
20	.....	.....	.....	7/8	1 7/16	1 9/16	1 7/16	1 7/16	1 3/4	15/16	1 5/16	1 1/2	15/16	1 1/4	1 1/2	.....	.....	.....
5	.....	.....	.....	1 5/8	1 3/4	2	1 1/2	1 3/4	1 7/8	1 3/8	1 3/4	1 7/8	1 1/2	1 3/4	1 7/8	1 3/8	1 1/2	1 3/4
17	.....	.....	.....	7/8	1 1/4	1 7/8	7/8	1 1/4	1 7/8	7/8	1 1/4	1 7/8	7/8	1 1/2	1 7/8	.....	.....	.....
21	.....	1 1/2	.....	.....	1 1/2	.....	.....	1 1/2	.....	.....	1 1/2	.....	.....	1 1/2	.....	.....	.....	.....
21	.....	1 1/2	.....	.....	1 1/2	.....	.....	1 1/2	.....	.....	1 1/2	.....	.....	1 1/2	.....	.....	.....	.....
10	.....	.....	.....	1 3/8	1 5/8	1 3/4	1 1/4	1 1/2	1 5/8	1 1/4	1 1/2	1 5/8	1 1/4	1 1/2	1 5/8	1 1/4	1 1/2	1 5/8
36	.....	.....	.....	1 3/8	1 5/8	2 1/4	1 1/8	1 3/8	2	1	1 1/4	1 7/8	7/8	1 1/8	1 3/4	.....	.....	.....
16	.....	.....	.....	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	1 1/8	1 1/4	1 3/8	.....	.....	.....
27	.....	.....	.....	1 1/4	1 1/2	2	1 1/4	1 1/2	2	1 1/8	1 1/2	2	1 1/8	1 1/2	2	.....	.....	.....
13	.....	.....	.....	1 5/8	1 3/4	2 1/8	1 5/16	1 15/16	2 3/16	1 15/16	1 15/16	2 3/16	.....	.....	.....	.....	.....	.....
34	.....	.....	.....	1 1/8	1 1/4	1 1/2	1	1 1/8	1 1/4	1	1 1/8	1 1/4	7/8	1	1 1/8	.....	.....	.....
33	.....	.....	.....	1	1 1/4	1 5/8	3/4	1 1/4	1 1/2	1	1 5/16	1 7/16	3/4	1	1 3/16	.....	.....	.....
25	.....	.....	.....	.....	2 1/2	.....	.....	2 1/2	.....	.....	2	.....	.....	2	.....	.....	1 3/4	.....
30	1 1/2	1 3/4	2	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	1 1/8	1 3/8	1 5/8	.....	.....	.....
2	.....	.....	.....	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	.....	.....	.....
7	.....	.....	.....	1	1 1/4	2 1/4	7/16	1 1/8	1 3/4	5/16	13/16	1 3/4	1/2	1 1/4	2 1/4	.....	.....	.....
14	.....	.....	.....	1	1 1/2	1 3/4	1	1 1/2	1 3/4	1	1 1/2	1 3/4	.....	.....	.....	.....	.....	.....
35	.....	.....	.....	1 1/4	1 5/8	1 3/4	1 1/8	1 3/8	1 1/2	1	1 1/4	1 3/8	7/8	1	1 1/4	.....	.....	.....
12	.....	.....	.....	1 5/8	1 3/4	2	1 3/8	1 5/8	2 1/16	1 1/4	1 11/16	2 1/8	.....	.....	.....	.....	.....	.....
41	.....	.....	.....	1 1/4	1 7/16	1 3/4	11/16	1 1/16	1 5/16	9/16	15/16	1 5/8	.....	.....	.....	.....	.....	.....
43	.....	.....	.....	1 1/8	1 1/2	1 7/8	1	1 3/8	1 7/8	3/4	1	1 3/4	.....	.....	.....	.....	.....	.....
15	.....	.....	.....	11/16	1 3/8	1 3/4	1 1/8	1 1/4	1 3/4	1 1/8	1 1/4	1 3/4	1	1 1/8	1 1/2	.....	.....	.....
19	.....	.....	.....	1	1 1/2	2	7/8	1 3/8	2	7/8	1 3/8	2	.....	.....	.....	.....	.....	.....
24	.....	.....	.....	1 1/8	1 7/16	1 15/16	1 1/4	1 5/16	1 3/4	1	1 3/16	2	15/16	1 3/16	1 7/8	.....	.....	.....
38	.....	.....	.....	1	1 1/4	1 1/2	1	1 1/4	1 1/2	7/8	1 1/4	1 1/2	3/4	1	1 1/4	.....	.....	.....
37	3/8	3/4	1	3/4	1 1/8	1 3/16	3/8	7/8	1	3/8	3/4	1	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	1 1/4	1 3/8	1 3/4	7/8	1	1 3/8	3/4	7/8	1 1/4	.....	.....	.....	.....	.....	.....
26	.....	.....	.....	1 1/8	1 1/4	1 1/2	1 1/4	1 3/8	1 1/2	1	1 1/4	1 1/2	7/8	1 1/8	1 3/8	.....	.....	.....
31	3/8	3/4	1 1/4	7/8	1 5/16	1 7/8	11/16	1 1/4	1 3/4	9/16	15/16	1 7/16	.....	.....	.....	.....	.....	.....
32	.....	.....	.....	1 1/4	1 1/8	1 3/8	1 1/8	1 1/8	1 3/8	1	1 1/4	1 5/8	.....	.....	.....	.....	.....	.....
1	7/8	1 1/8	1 3/4	1	1 1/2	1 3/4	1	1 1/2	1 3/4	1	1 1/2	1 3/4	.....	.....	.....	.....	.....	.....
40	1 3/8	1 5/8	2 1/2	1 1/8	1 3/8	1 7/8	1 3/16	1 5/16	1 3/4	3/4	1	1 5/8	.....	.....	.....	.....	.....	.....
23	5/8	7/8	1 1/4	3/4	1 3/8	1 1/2	1 1/2	1 7/8	2 1/8	7/8	1 3/8	2	.....	.....	.....	.....	.....	.....
9	.....	.....	.....	1	1 1/8	1 1/4	7/8	1	1 3/8	7/8	1	1 1/2	11/16	7/8	1 3/8	.....	.....	.....
47	.....	.....	.....	1 1/4	1 1/2	2	3/4	1 1/4	1 7/8	1/2	1	1 1/2	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	1	1 1/4	1 3/4	1	1 1/4	1 3/4	1	1 1/4	1 3/4	.....	.....	.....	.....	.....	.....
29	.....	.....	.....	11/16	13/16	1 1/4	11/16	7/8	1 3/16	.....	.....	.....	.....	.....	.....	.....	.....	.....
39	.....	.....	.....	2	2 1/4	2 1/2	1 1/2	1 3/4	2	1 11/16	1 7/8	2 1/16	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	1 1/4	1 1/2	1 3/4	1 1/4	1 1/2	1 3/4	3/4	1	1 1/8	3/4	1	1 1/8	.....	.....	.....
18	3/4	1	1 1/4	1	1 1/4	1 1/2	7/8	1 1/8	1 1/2	1	1 1/4	1 5/8	.....	.....	.....	.....	.....	.....

RETURNER BAR — WIDTH—INCHES; DISTANCE FROM BACK ROLLER—INCHES

Factory No.	Width 1st Mill	Width 2nd Mill	Width 3rd Mill	Width 4th Mill	Width 5th Mill	Width 6th Mill	Back Roller 1st Mill	Back Roller 2nd Mill	Back Roller 3rd Mill	Back Roller 4th Mill	Back Roller 5th Mill	Back Roller 6th Mill
6	12 1/8	12 3/4	12 3/4	13 1/4	......	......	1/2	1/2	1/2	1/2	...	...
6	12 1/4	12 3/8	12 5/8	13 1/4	......	......	1/2	1/2	1/2	1/2	...	...
20	12 1/2	15 5/8	12	15 1/2	......	......	3/4	5/8	1 1/8	9/16	...	...
20	14 1/2	14	16	16	......	......	1	1	7/8	5/8	...	...
5	13	13	13 1/2	13 1/2	13	13 1/2	1	3/4	1/2	3/4	1/2	3/8
17	14 3/4	14 3/4	14 3/4	15	......	......	1/2	1/2	1/2	3/8	...	...
21	......	......	......	......	......	......	...	...	...	...	...	...
21	......	......	......	......	......	......	...	...	...	...	...	...
10	12 3/4	12 3/4	12 3/4	12 3/4	12 3/4	......	3/8	3/8	3/8	3/8	3/8	...
36	15 1/2	15 1/2	15	12 1/2	......	......	1/2	1/2	1/2	1/2	...	...
16	14 1/4	14 1/2	15	15	......	......	3/8	3/8	3/8	3/8	...	...
27	14	14	14	14	......	......	1/2	1/2	1/2	1/2	...	...
13	13 1/2	13	12	......	......	......	9/16	1	1	...	...	...
34	12	12	12	12 1/4	......	......	1/4	1/2	3/8	3/8	...	...
33	12 1/2	11 5/8	11 13/16	11 7/8	......	......	1/2	1/2	1/2	1/2	...	...
25	12	11 1/2	11 1/2	11 1/2	11 1/2	......	3/8	3/8	3/8	3/8	3/8	...
30	12 1/2	12 1/2	12 1/2	12 1/2	......	......	1/2	1/2	1/2	3/8	...	...
2	12 3/4	12 3/4	13 7/8	15	......	......	3/4	1/2	9/16	1/2	...	...
7	11 5/8	12	12 3/8	12 1/4	......	......	1/2	1/2	7/16	7/16	...	...
14	13 3/4	13 3/4	13 3/4	......	......	......	1/2	1/2	1/2	...	...	...
35	12 1/2	12 1/2	12	12 1/2	......	......	1/2	1/2	1/2	3/8	...	...
12	13	12 1/2	12 1/4	......	......	......	1/2	1/2	3/8	...	...	...
41	10 7/16	11	12 3/8	......	......	......	5/8	5/8	5/8	...	...	...
43	15 1/4	14 1/2	12 3/4	......	......	......	3/4	3/4	5/8	...	...	...
15	11	12 1/4	12 3/8	11 3/4	......	......	5/8	5/8	1/2	3/8	...	...
19	14	13	13	......	......	......	3/8	3/8	3/8	...	...	...
24	11 1/2	10 3/4	12 1/2	11 11/16	......	......	5/8	13/16	5/8	1/2	...	...
38	11	11 1/2	11	11	......	......	1/2	1/2	3/8	1/4	...	...
37	12 1/2	12 3/4	12 3/4	......	......	......	7/8	3/4	3/4	...	...	...
3	12 1/2	12 1/2	12 1/2	......	......	......	1/4	1/4	1 1/4	...	...	...
26	10 1/2	10 1/2	10 3/4	10 1/2	......	......	3/4	3/4	3/4	1	...	...
31	11 7/8	12 1/4	12 1/2	......	......	......	3/8	1/2	7/16	...	...	...
32	10 1/2	11	13	......	......	......	1 1/4	1	1/2	...	...	...
1	10 3/4	11	11	......	......	......	3/8	3/8	3/8	...	...	...
40	12 1/2	11 1/2	12	......	......	......	3/4	5/8	1/2	...	...	...
23	12	11	12	......	......	......	3/4	1 1/4	3/4	...	...	...
9	12 1/2	12 1/2	13 1/4	13 1/2	......	......	1	1 1/2	1/4	3/8	...	...
47	13	12	11 3/4	......	......	......	1/2	1/2	1/2	...	...	...
11	10 3/4	11	11 1/4	......	......	......	1	1/2	1/2	...	...	...
29	10 1/8	10	......	......	......	......	3/8	3/8	...	...	...	...
39	12	9	14	......	......	......	3/4	3/4	1/2	...	...	...
4	9	11	10	10	......	......	1/2	1/4	1/2	1/4	...	...
18	11	11	11	......	......	......	1/4	1/4	5/16	...	...	...

SPEED OF ROLLERS—FEET PER MINUTE; PRESSURE ON ROLLERS—TONS

Factory No.	Speed: Crusher	Speed: 1st Mill	Speed: 2nd Mill	Speed: 3rd Mill	Speed: 4th Mill	Speed: 5th Mill	Speed: 6th Mill	Pressure: Crusher	Pressure: 1st Mill	Pressure: 2nd Mill	Pressure: 3rd Mill	Pressure: 4th Mill	Pressure: 5th Mill	Pressure: 6th Mill	Tons Cane per Hour	Tonnage Ratio	Factory No.	Factory
6	30	25	24	30	24	...	...	190	400	375	460	460	...	...	64.60*	1.82	6	[illegible]
6	30	25	24	31	24	...	...	190	400	375	460	460	...	...			6	[illegible]
20	35.5	24.4	19.4	21.7	23.3	...	...	285	579	523	537	517	...	...	67.20*	1.91	20	[illegible]
20	38.8	26.7	19.4	22.2	22.7	...	...	228	523	427	437	466	...	...			20	[illegible]
5	23.3	21.8	23.5	26.5	26.2	30.7	35	292	438	450	450	293	408	488	86.95	1.76	5	[illegible]
17	29.9	28.1	28.1	29	31.3	...	...	300	490	490	500	500	...	..	88.15	[illegible]	17	[illegible]
21	23	24	25	28	25	...	...	400	500	500	520	[illegible]	...	..	50.43	2.00	21	[illegible]
21	23	24	25	28	25	...	...	400	500	500	520	[illegible]	...	...			21	[illegible]
10	51.9	30.1	31.3	28.1	28.1	31.4	...	298	486	440	[illegible]	[illegible]	[illegible]	...	79.98	2.20	10	[illegible]
36	...	23.9	26.1	29.8	35.1	...	...	...	350	320	340	420	...	...	65.55	[illegible]	36	[illegible]
16	30.6	20.2	23	22.7	23.8	...	...	250	458	474	489	504	...	...	57.53	1.63	16	[illegible]
27	53.1	32.2	32.2	31.4	35	...	...	309	451	432	476	455	...	...	77.09	2.19	27	[illegible]
13	21.4	19.4	22.7	23.6	...	...	...	260	498	475	496	...	...	...	51.49	1.82	13	[illegible]
34	23.2	21.6	21.3	21.4	21.5	...	...	54	428	430	410	455	...	...	49.58	1.06	34	[illegible]
33	40.2	24.5	23.3	26.4	17.9	...	...	153	395	395	395	420	...	...	45.57	1.61	33	[illegible]
25	22	17	18.7	20	20	20	...	...	350	350	379	381	399	...	46.21	1.87	25	[illegible]
30	23.8	22.2	22.5	25.1	27.3	...	...	357	286	405	403	405	...	...	[illegible]	1.96	30	[illegible]
2	30.3	19.5	16.8	17.8	22.3	...	...	190	400	400	400	[illegible]	...	...	[illegible]	[illegible]	2	[illegible]
7	30.5	21.6	24.2	26.5	15.8	...	...	...	322	322	345	380	...	...	36.27	1.74	7	[illegible]
14	52.6	19.3	22.6	25.5	...	...	...	250	437	460	448	...	...	...	52.17	2.17	14	[illegible]
35	34.2	24.5	20.9	25.4	28	...	...	225	580	380	390	405	...	...	41.72	1.66	35	[illegible]
12	33.5	19.5	19.5	20.5	...	...	...	250	475	495	512	...	...	...	46.43	1.42	12	[illegible]
41	30.5	21.5	17.4	19.3	...	...	...	250	374	374	374	...	...	...	27.94	1.68	41	[illegible]
43	31.5	16.3	18.5	21.4	...	...	...	135	[illegible]	450	490	...	...	...	37.78	1.57	43	[illegible]
15	30.5	19.7	19.7	20.1	24.2	...	...	...	380	370	370	400	...	...	29.22	1.4	[illegible]	[illegible]
19	31.4	21.7	23.7	26.1	...	...	...	...	385	385	385	...	...	...	30.80	1.85	19	[illegible]
24	22	13.5	17.1	19	21	...	...	...	389	360	365	393	...	...	27.78	1.10	24	[illegible]
38	24.8	17.3	19	17.6	19.5	...	...	...	400	400	400	400	...	...	35.50	1.41	38	[illegible]
37	20.4	17.6	20.2	22.4	...	...	...	356	224	333	533	...	...	...	25.23	1.51	37	[illegible]
3	26.7	18.6	20.9	23	...	...	...	140	360	350	360	...	...	...	26.68	1.60	3	[illegible]
26	38.2	27.3	21.9	23	23	...	...	155	300	382	300	325	...	...	29.0	1.72	26	[illegible]
31	19.8	17.2	19.2	21.7	...	...	...	350	371	382	382	...	...	...	32.61	1.96	31	[illegible]
32	22.3	17.7	19.8	22.4	...	...	...	...	318	308	295	...	...	...	28.58	1.71	32	[illegible]
1	20.7	19.6	18.6	18.7	...	...	...	350	360	350	350	...	...	...	26.75	1.97	1	[illegible]
40	22	19	25	28	...	...	...	...	350	340	360	...	...	...	27.21	1.63	40	K[illegible]
23	18	19.5	20.5	20.5	...	...	...	300	320	319	312	...	...	...	25.5	1.73	23	K[illegible]
9	...	16.9	16.9	16.9	17.6	...	...	...	311	320	332	351	...	...	25.45	1.53	9	Waianae
47	19.8	16.6	18	20.4	...	...	...	...	347	330	355	...	...	...	31.43	1.89	47	Kaeleku
11	...	16	19	21	...	...	...	...	380	304	330	...	...	...	21.50	1.79	11	Union Mill
29	16	18	14	...	...	...	...	100	189	239	...	...	...	...	14.49	1.67	29	Halawa
39	...	20.2	22	22	...	...	...	...	202	218	218	...	...	...	19.05	1.88	39	Ni[illegible]
4	20.4	13.2	14.1	13.6	17	...	...	...	215	...	154	154	...	...	15.15	1.48	4	W[illegible]
18	23.1	23.1	26.1	26.1	...	...	...	220	220	260	260							

* Tons of Cane for one tandem.
† 5th Mill opening 5/8x0, returner bar from top roller, 1 1/4, 1 3/4, 1 3/4.
‡ Point to point.

CANE MILL DATA, SEASON OF 1928 (CONTINUED) ROLLER GROOVING

Factory	Factory No.	MILLING PLANT	Surface Grooves per Inch Top, Front, Back: Crusher	1st Mill	2nd Mill	3rd Mill	4th Mill	5th Mill	6th Mill
H. C. & S. Co.	6	K(2),2RC78,S72,12RM78	Krajewski	4, 1 1/3, 1 1/3	4, 1 1/3, 8	4, 1 1/3, 8	4, 1 1/3, 8	....	....
"	6	K(2),2RC78,S72,12RM78	Krajewski	4, 1 1/3, 1 1/3	4, 1 1/3, 8	4, 1 1/3, 8	4, 1 1/3, 8	....	....
Oahu	20	K,2RC78,S72,12RM78	Krajewski	2 2/3, 1 1/3, 2 2/3	2 2/3, 1 1/3, 2 2/3	2 2/3, 1 1/3, 2 2/3	7, 1 1/3, 7	....	....
"	20	K,2RC78,S72,12RM78	Krajewski	2 2/3, 1 1/3, 2 2/3	2 2/3, 1 1/3, 2 2/3	2 2/3, 1 1/3, 2 2/3	7, 1 1/3, 7	....	....
Ewa	5	K(2),2RC78,18RM78	1, 1	1 1/3, 1 1/3, 1 1/3	2 2/3, 1 1/3, 2 2/3	2 2/3, 1 1/3, 5 1/3	1 1/3, 1 1/3, 2 2/3	2 2/3, 1 1/3, 5 1/3	5 1/3, 1 1/3, 5 1/3
Waialua	17	K(2),2RC78,12RM78	4/5, 4/5	1 1/3, 1 1/3, 1 1/3	1 1/3, 1 1/3, 1 1/3	2 2/3, 1 1/3, 2 2/3	2 2/3, 2 2/3, 2 2/3	....	....
Maui Agr.	21	K(2),3RC66,12RM66	2/3, 2/3, 2/3	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	....	....
" "	21	K(2),3RC66,12RM66	2/3, 2/3, 2/3	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	....	....
Pioneer	10	K,2RC72,S72,15RM72	Krajewski	1 1/3, 1 1/3, 1 1/3	7, 1 1/3, 7	7, 1 1/3, 7	7, 1 1/3, 7	7, 1 1/3, 7	....
Olaa	36	K,S72,12RM78	....	3, 3, 6	6, 3, 6	6, 3, 6	6, 3, 6	....	....
Haw. Sug.	16	K,2RC72,S72,12RM78	Krajewski	4, 4, 4	4, 4, 4	4, 4, 4	7, 4, 7	....	....
Lihue	27	K,2RC78,S72,12RM78	Krajewski	1 1/3, 1 1/3, 7	7, 1 1/3, 7	7, 1 1/3, 7	7, 1 1/3, 7	....	....
Honolulu	13	K(2),S54,2RC78,9RM78	2/5, 2/5	1 1/3, 1 1/3, 1 1/3	6, 1 1/3, 6	6,1 1/3, 6	....	....	....
Onomea	34	2RC60,S54,12RM66	Krajewski	4, 4, 7	7, 4, 7	7, 4, 7	7, 4, 7	....	....
Hilo	33	K,2RC66,12RM66	Krajewski	5, 1, 5	5, 5, 5	5, 5, 5	5, 5, 5	....	....
Kekaha	25	2RC54,15RM60	Krajewski	8/9, 8/9, 8/9	7, 7, 7	7, 7, 7	7, 7, 7	7, 7, 7	....
Haw. Agr.	30	K,3RC60,12RM66	2/3, 2/3, 2/3	1 1/3, 1 1/3, 1 1/3	4, 4, 4	5, 1 1/3, 5	5, 4, 5	....	....
Wailuku	2	K,2RC72,12RM78	Krajewski	1 1/3, 1 1/3, 1 1/3	4, 4, 4	4, 4, 4	4, 4, 4	....	....
Hakalau	7	2RC54,12RM9-60,3-66	Krajewski	5, 5, 5	7, 5, 7	7, 7, 7	7, 7, 7	....	....
Makee	14	K,2RC72,9RM72	Krajewski	1 1/3, 1 1/3, 0	3, 3, 7	7, 7, 7	....	....	....
Honokaa	35	K(2),2RC66,12RM66	2/3, 2/3	5, 5, 5	5, 5, 5	5, 5, 5	5, 5, 5	....	....
McBryde	12	K,2RC72,S72,9RM84	Krajewski	6, 6, 6	6, 6, 6	6, 6, 6	....	....	....
Laupahoehoe	41	K,2RC60,9RM60	3/4, 3/4	5, 3 1/2, 5	6, 4, 6	8, 4, 8	....	....	....
Kahuku	43	K,2RC60,S54,9RM72	Krajewski	3, 2, 4	4, 4, 4	4, 4, 4	....	....	....
Hamakua	15	K,2RC60,12RM60	Krajewski	6, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	....	....
Pepeekeo	19	2RC54,9RM60	Krajewski	7, 4, 7	7, 7, 7	7, 7, 7	....	....	....
Paauhau	24	2RC60,12RM66	Krajewski	4, 2 2/3, 4	7, 4, 7	7, 4, 7	7, 7, 7	....	....
Koloa	38	K,2RC60,12RM66	Krajewski	2 2/3, 2 2/3, 5 1/4	5 1/4, 2 2/3, 5 1/4	5 1/4, 5 1/4, 5 1/4	5 1/4, 5 1/4, 5 1/4	....	....
Honomu	37	3RC60,9RM60	2/3, 2/3, 2/3	6, 6, 7	6, 6, 6	6, 6, 6	....	....	....
Waiakea	3	K,2RC60,9RM60	Krajewski	4, 4, 4	7, 4, 7	7, 4, 7	....	....	....
Hawi	26	K(2),2RC54,12RM54	4/5, 4/5	2, 1 1/3, 2	3, 2, 3	4, 4, 4	4, 4, 4	....	....
Hutchinson	31	K,3RC60,9RM60	2/3, 2/3, 2/3	4, 4, 4	4, 4, 4	4, 4, 4	....	....	....
Kaiwiki	32	K,2RC60,9RM60	Krajewski	6, 3, 6	6, 6, 6	6, 6, 6	....	....	....
Waimanalo	1	K,3RC54,9RM54	2/3, 2/3, 2/3	4, 4, 4	4, 4, 4	4, 4, 4	....	....	....
Kohala	40	K(2),3RC60,9RM60	2 1/2, 2 1/2, 4	5, 2 1/2, 5	5, 5, 5	5, 5, 7	....	....	....
Kilauea	23	K,3RC60,9RM60	8/9, 8/9, 8/9	4, 1, 7	7, 4, 7	7, 4, 7	....	....	....
Waianae	9	K,12RM60	....	1, 1, 1	6, 2, 6	7, 7, 7	7, 7, 7	....	....
Kaeleku	47	K,2RC54,9RM60	Krajewski	3, 3, 3	5, 5, 5	5, 5, 5	....	....	....
Union Mill	11	K,9RM60	....	2 1/2, 2, 2 1/2	5, 2 1/2, 5	7, 2 1/2, 7	....	....	....
Halawa	29	K,2RC60,6RM50	8/9, 8/9	4, 4, 4	4, 4, 4	....	....	....	....
Niulii	39	K,9RM54	....	2, 2, 2	4, 4, 4	6, 6, 6	....	....	....
Waimea	4	2RC48,12RM42	Krajewski	8/9, 8/9, 8/9	4, 4, 8	8, 4, 8	8, 4, 8	....	....
Olowalu	18	K,3RC48,9RM48	2/3, 2/3, 2/3	5, 5, 5	5, 5, 5	5, 5, 5	....	....	....

JUICE GROOVES

Factory No.	1st Mill Front Width	Depth	Pitch	1st Mill Back Width	Depth	Pitch	2nd Mill Front Width	Depth	Pitch	2nd Mill Back Width	Depth	Pitch	3rd Mill Front Width	Depth	Pitch	3rd Mill Back Width	Depth	Pitch
6	7/32	2 1/4	2 1/4	—	—	—	7/32	2 1/4	2 1/4	7/32	2	2	7/32	2 1/4	2 1/4	7/32	2	3
6	7/32	2 1/4	2 1/4	—	—	—	7/32	2 1/4	2 1/4	7/32	2	2	7/32	2 1/4	2 1/4	7/32	2	3
20	5/16	2	2 1/4	5/16	1 1/2	2 5/8	5/16	2	3 3/4	5/16	1 1/2	2 5/8	5/16	2	3 3/4	5/16	2	2 5/8
20	5/16	2	2 1/4	3/8	1 1/2	2 5/8	5/16	2	3 3/4	5/16	1 1/2	2 5/8	5/16	2	3 3/4	5/16	1 1/2	2 5/8
5	1/4	2	3	1/4	2	3	1/4	1 3/4	3	5/32	1 3/4	3	1/4	1 3/4	3	5/32	1 3/4	3
17	5/16	1 3/4	4	5/16	1 3/4	4	5/16	1 3/4	4	5/16	1 3/4	4	5/16	1 3/4	4	5/16	1 3/4	4
21	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3
21	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3
10	3/16	2	2 1/4	—	—	—	3/16	2	2 1/4	3/16	2	2 1/4	3/16	2	2 1/4	3/16	2	2 1/4
36	3/16	1 3/8	3	3/16	1 3/8	2	3/16	1 3/8	3	3/16	1 3/8	2	3/16	1 3/8	3	3/16	1 3/8	2
16	3/8	1 1/2	2	1/4	1 1/2	2	1/4	1 1/2	2	3/16	1 1/2	2	3/16	1 1/2	2	1/8	1 1/2	3
27	5/16	1 1/2	3	5/16	1 1/2	3	5/16	1 1/2	3	3/16	1 1/2	3	3/8	1 1/2	3	1/4	1 1/2	3
13	1/4	1 1/2	3	1/4	1 1/2	3	1/4	1 1/2	3	3/16	1 1/2	3	1/4	1 1/2	3	1/4	1 1/2	3
34	1/4	1 1/2	2	3/16	1 1/2	2	1/4	1 1/2	2	5/16	1 1/2	2	1/4	1 1/2	2	3/16	1 1/2	2
33	1/4	2	2	1/8	1 1/2	2	1/4	2	2	1/8	1 1/2	2	1/4	2	2	1/8	1 1/2	2
25	—	—	—	—	—	—	1/4	1 3/8	2	3/16	1 3/8	2	1/4	1 3/8	2	3/16	1 3/8	2
30	1/4	1 1/2	3	1/4	1 1/2	3	3/16	1 1/2	2	3/16	1 1/2	2	3/16	1 1/2	2	3/16	1 1/2	2
2	3/16	1 1/2	2 1/4	3/16	1 1/2	2 1/4	1/4	1 1/2	2	5/32	1 1/2	2	3/8	1 1/2	4	3/16	1 1/2	2
7	1/4	1 1/2	2	1/8	1 1/2	2	1/4	1 1/2	2	1/8	1 1/2	2	1/4	1 1/2	2	1/8	1 1/2	2
14	3/16	1 1/2	4	3/16	1 1/2	2	3/16	1 1/2	4	3/16	1 1/2	2	3/16	1 1/2	2	3/16	1 1/2	2
35	1/4	1 5/8	2	1/4	1 3/4	2	1/4	1 1/2	2	1/4	1 1/2	2	3/16	1 3/4	2 1/4	3/16	1 3/4	2 1/4
12	1/4	1 1/2	3	1/4	1 1/2	2 1/2	1/4	1 1/2	3	1/4	1 1/2	2 1/2	1/4	1 1/2	3	1/4	1 1/2	2 1/2
41	3/16	1 1/2	2	3/16	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	2 3/4	3/16	1 1/2	2 3/4	3/16	1 1/2	2 3/4
43	5/16	1 1/2	2	1/4	1 1/2	3	1/4	1 1/2	2	1/4	1 1/2	3	1/4	1 1/2	3	1/4	1 1/2	3
15	7/32	1 1/2	2 1/4	7/32	1 1/2	2 1/4	7/32	1 1/2	2 1/4	7/32	1 1/2	2 1/4	7/32	1 1/2	2 1/4	7/32	1 1/2	2 1/4
19	1/4	1 1/2	3	5/32	1 1/2	2	1/4	1 1/2	3	5/32	1 1/2	2	1/4	1 1/2	3	5/32	1 1/2	2
24	9/64	1 1/2	2 1/4	9/64	1 1/4	2	9/64	1 1/2	2	9/64	1 1/4	2	9/64	1 1/2	2	9/64	1 1/4	2
38	5/16	1 3/8	2 5/8	1/4	1 1/2	2 5/8	1/4	1 3/8	2 5/8	1/4	1 1/16	2 5/8	5/16	1 3/8	2 5/8	1/4	1 1/2	2 5/8
37	5/32	1 3/4	2	5/32	1 3/4	2	5/32	1 3/4	2	5/32	1 3/4	2	5/32	1 3/4	2	5/32	1 3/4	2
3	1/4	1 1/2	2 1/2	1/4	1 1/2	2 1/2	1/4	1 1/2	2 1/2	1/4	1 1/2	3	1/4	1 1/2	2 1/2	1/4	1 1/2	2 1/2
26	5/16	1 1/2	2 1/2	5/16	1 1/2	2 1/2	1/4	1 1/2	2	1/4	1 1/2	3	3/16	1 1/2	2 1/2	3/16	1 1/2	3
31	1/2	1 1/2	3	1/4	1 1/2	2	1/4	1 1/2	2	3/16	1 1/2	2	3/16	1 1/2	2	1/8	1 3/4	2
32	1/4	1 1/2	2 1/2	1/4	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	3	1/8	1 1/2	3
1	3/8	1 1/2	2	3/8	1 1/2	2	3/16	1 1/2	2	3/16	1 1/2	2	1/8	1 1/2	2	1/8	1 1/2	2
40	3/16	1 1/2	2 3/4	3/16	1 1/2	2 1/2	3/16	1 1/2	2 1/2	3/16	1 1/2	2 1/2	3/16	1 1/2	3	1/8	1 1/2	2 1/2
23	1/4	1 1/4	2	1/2	1 1/4	2	1/2	1 3/4	2	1/8	1 1/2	3	3/8	1 5/8	2	1/8	1 1/2	2
9	—	—	—	—	—	—	1/8	1 1/4	2	1/8	1 1/4	2	1/8	1 1/4	2	1/8	1 1/4	2
47	1/4	1 1/2	2	1/8	1 1/4	2	1/4	1 1/2	2	1/8	1 1/4	2	1/4	1 1/2	3	1/8	1 1/4	2
11	—	—	—	—	—	—	1/4	1	3	1/4	1 1/8	3	1/4	1	3	3/16	1 1/4	3
29	5/16	1 1/4	2	3/16	1 1/4	2	5/16	1 1/4	2	3/16	1 1/4	2	....	....	....	....	....	....
39	1/4	1 1/2	3	1/4	1 1/2	3	1/4	1 1/2	3	1/4	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	3
4	—	—	—	—	—	—	1/4	1 1/4	2	3/16	1 1/4	2	5/16	1 1/2	2	1/8	1 1/2	2
18	3/16	1	2	3/16	1	2	3/16	1	2	3/16	1	2	3/16	1	2	3/16	1	2

Factory No.	4th Mill Front Width	Depth	Pitch	4th Mill Back Width	Depth	Pitch	5th Mill Front Width	Depth	Pitch	5th Mill Back Width	Depth	Pitch	6th Mill Front Width	Depth	Pitch	6th Mill Back Width	Depth	Pitch	Factory No.	Factory
6	7/32	2 1/4	2 1/4	7/32	2	2	....	....	....	....	....	....	....	....	....	....	....	....	6	H. C. & S. Co.
6	7/32	2 1/4	2 1/4	7/32	2	2	....	....	....	....	....	....	....	....	....	....	....	....	6	"
20	5/16	2	3 3/4	5/16	1 1/2	2 5/8	....	....	....	....	....	....	....	....	....	....	....	....	20	Oahu
20	5/16	2	3 3/4	5/16	1 1/2	2 5/8	....	....	....	....	....	....	....	....	....	....	....	....	20	"
5	1/4	1 3/4	3	5/32	1 3/4	3	1/4	1 3/4	3	5/32	1 3/4	3	1/4	1 3/4	3	5/32	1 3/4	3	5	Ewa
17	5/16	1 3/4	4	5/16	1 3/4	4	....	....	....	....	....	....	....	....	....	....	....	....	17	Waialua
21	5/16	1 1/2	3	5/16	1 1/2	3	....	....	....	....	....	....	....	....	....	....	....	....	21	Maui Agr.
21	5/16	1 1/2	3	5/16	1 1/2	3	....	....	....	....	....	....	....	....	....	....	....	....	21	" "
10	3/16	2	2 1/4	3/16	2	2 1/4	3/16	2	2 1/4	3/16	2	2 1/4	....	....	....	....	....	....	10	Pioneer
36	3/16	1 3/8	3	3/16	1 3/8	2	....	....	....	....	....	....	....	....	....	....	....	....	36	Olaa
16	3/16	1 1/2	2	1/8	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	16	Haw. Sug.
27	1/4	1 1/2	3	3/16	1 1/2	3	....	....	....	....	....	....	....	....	....	....	....	....	27	Lihue
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13	Honolulu
34	1/4	1 1/2	2	5/32	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	34	Onomea
33	1/4	2	2	1/8	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	33	Hilo
25	3/16	1 3/8	2	1/8	1 3/8	2	3/16	1 3/8	2	1/8	1 3/8	2	....	....	....	....	....	....	25	Kekaha
30	3/16	1 1/2	2	1/8	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	30	Haw. Agr.
2	1/8	1 1/2	2	1/8	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	2	Wailuku
7	1/4	1 1/2	2	1/8	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	7	Hakalau
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14	Makee
35	5/32	1 3/4	2 1/4	5/32	1 3/4	2 1/4	....	....	....	....	....	....	....	....	....	....	....	....	35	Honokaa
12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12	McBryde
41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	41	Laupahoehoe
43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	43	Kahuku
15	7/32	1 1/2	2 1/4	7/32	1 1/2	2 1/4	....	....	....	....	....	....	....	....	....	....	....	....	15	Hamakua
19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	19	Pepeekeo
24	9/64	1 1/2	2	9/64	1 1/4	2	....	....	....	....	....	....	....	....	....	....	....	....	24	Paauhau
38	1/4	1 1/2	2 5/8	1/4	1 1/2	2 5/8	....	....	....	....	....	....	....	....	....	....	....	....	38	Koloa
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	37	Honomu
3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	Waiakea
26	1/8	1 3/4	2	1/8	1 3/4	2	....	....	....	....	....	....	....	....	....	....	....	....	26	Hawi
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	31	Hutchinson
32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	32	Kaiwiki
1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	Waimanalo
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	40	Kohala
23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	23	Kilauea
9	1/8	1 1/4	2	1/8	1 1/4	2	....	....	....	....	....	....	....	....	....	....	....	....	9	Waianae
47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	47	Kaeleku
11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	11	Union Mill
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	29	Halawa
39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	39	Niulii
4	5/16	1 1/2	2	1/8	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	4	Waimea
18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	18	Olowalu

TABLE NO. 10

SUMMARY OF LOSSES

FACTORY	POUNDS POLARIZATION PER TON OF CANE						POLARIZATION PER 100 CANE						POLARIZATION PER 100 POLARIZATION OF CANE						Syrup Purity	FACTORY
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL		
H. C. & S. Co.	8.00	...	16.40	...	—1.20	23.20	0.40	...	0.82	...	—0.06	1.16	2.65	...	5.53	...	—0.42	7.76	88.33	H. C. & S. Co.
Oahu	5.60	2.20	15.80	1.80	—0.20	25.20	0.28	0.11	0.79	0.09	—0.01	1.26	2.08	0.84	5.92	0.67	—0.05	9.46	86.67	Oahu
Ewa	5.00	1.40	18.00	...	1.60	26.00	0.25	0.07	0.90	...	0.08	1.30	1.96	0.54	6.93	...	0.59	10.02	85.03	Ewa
Waialua	8.20	1.20	21.00	...	3.00	33.40	0.41	0.06	1.05	...	0.15	1.67	3.04	0.46	7.83	...	1.12	12.45	85.6	Waialua
Maui Agr.	7.20	...	18.20	...	—2.80	22.60	0.36	...	0.91	...	—0.14	1.13	2.52	...	6.49	...	—1.02	7.99	87.41	Maui Agr.
Pioneer	7.60	0.80	19.80	...	0.20	28.40	0.38	0.04	0.99	...	0.01	1.42	2.72	0.32	7.07	...	0.06	10.17	85.20	Pioneer
Olaa	7.80	1.80	22.00	...	2.20	33.80	0.39	0.09	1.10	...	0.11	1.69	3.17	0.72	9.00	...	0.94	13.83	86.1	Olaa
Haw. Sug.	7.00	2.20	17.40	...	—0.80	25.80	0.35	0.11	0.87	...	—0.04	1.29	2.48	0.75	6.11	...	—0.28	9.06	87.59	Haw. Sug.
Lihue	5.80	1.20	17.80	...	2.60	27.40	0.29	0.06	0.89	...	0.13	1.37	2.51	0.51	7.79	...	1.13	11.94	82.0	Lihue
Honolulu	8.60	1.40	27.00	...	....	....	0.43	0.07	1.35	...	....	...	3.16	0.51	10.00	...	....	....	86.7	Honolulu
Onomea	3.20	0.20	16.80	...	0.80	21.00	0.16	0.01	0.84	...	0.04	1.05	1.43	0.13	7.66	...	0.33	9.55	84.39	Onomea
Hilo	4.40	1.00	16.40	...	0.40	22.20	0.22	0.05	0.82	...	0.02	1.11	1.97	0.40	7.24	...	0.20	9.81	85.93	Hilo
Kekaha	5.60	1.40	23.60	...	1.40	32.00	0.28	0.07	1.18	...	0.07	1.60	2.13	0.52	9.06	...	0.56	12.27	84.09	Kekaha
Haw. Agr.	6.20	1.00	20.20	...	1.60	29.00	0.31	0.05	1.01	...	0.08	1.45	2.68	0.41	8.68	...	0.68	12.45	85.34	Haw. Agr.
Wailuku	4.80	1.20	20.40	...	—0.60	25.80	0.24	0.06	1.02	...	—0.03	1.29	1.77	0.43	7.62	...	—0.19	9.63	86.8	Wailuku
Hakalau	3.00	0.40	16.40	...	....	19.80	0.15	0.02	0.82	...	....	0.99	1.35	0.15	7.30	...	....	8.80	84.19	Hakalau
Makee	10.80	0.80	22.80	...	2.20	36.60	0.54	0.04	1.14	...	0.11	1.83	4.94	0.42	10.45	...	1.04	16.85	80.7	Makee
Honokaa	9.40	1.20	19.00	...	0.20	29.80	0.47	0.06	0.95	...	0.01	1.49	4.74	0.62	9.51	...	0.06	14.93	82.70	Honokaa
McBryde	8.40	1.00	17.60	...	0.80	27.80	0.42	0.05	0.88	...	0.04	1.39	3.32	0.41	6.91	...	0.28	10.92	84.86	McBryde
Laupahoehoe	7.20	0.40	13.40	...	3.00	24.00	0.36	0.02	0.67	...	0.15	1.20	2.95	0.17	5.55	...	1.23	9.90	87.46	Laupahoehoe
Kahuku	5.40	1.80	18.80	...	—3.60	22.40	0.27	0.09	0.94	...	—0.18	1.12	2.42	0.80	8.31	...	—1.55	9.98	81.89	Kahuku
Hamakua	6.30	...	15.40	...	1.80	24.00	0.34	...	0.77	...	0.09	1.20	2.80	...	6.27	...	0.71	9.78	85.67	Hamakua
Pepeekeo	5.60	0.40	15.80	...	0.20	22.00	0.28	0.02	0.79	...	0.01	1.10	2.34	0.17	6.66	...	0.12	9.29	84.89	Pepeekeo
Paauhau	5.60	1.00	21.00	...	1.60	29.20	0.28	0.05	1.05	...	0.08	1.46	2.50	0.47	9.43	...	0.71	13.11	84.57	Paauhau
Koloa	6.80	1.20	20.40	...	—1.00	27.40	0.34	0.06	1.02	...	—0.05	1.37	3.15	0.55	9.47	...	—0.44	12.73	81.4	Koloa
Honomu	4.40	0.40	17.20	...	....	22.00	0.22	0.02	0.86	...	....	1.10	1.85	0.20	7.20	...	—0.02	9.23	86.0	Honomu
Waiakea	10.40	2.20	22.60	...	4.60	39.80	0.52	0.11	1.13	...	0.23	1.99	4.39	0.95	9.56	...	1.98	16.88	85.39	Waiakea
Hawi	5.40	0.60	27.20	...	2.60	35.80	0.27	0.03	1.36	...	0.13	1.79	2.16	0.24	11.10	...	1.08	14.58	82.53	Hawi
Hutchinson	7.60	1.00	21.40	...	1.60	31.60	0.38	0.05	1.07	...	0.08	1.58	3.17	0.42	8.83	...	0.67	13.09	84.32	Hutchinson
Kaiwiki	9.60	2.20	21.00	...	0.60	33.40	0.48	0.11	1.05	...	0.03	1.67	3.84	0.87	8.40	...	0.27	13.38	85.72	Kaiwiki
Waimanalo	3.20	0.80	20.40	...	1.80	26.20	0.16	0.04	1.02	...	0.09	1.31	1.33	0.38	8.62	...	0.77	11.10	83.92	Waimanalo
Kohala	6.40	2.00	19.40	...	0.60	28.40	0.32	0.10	0.97	...	0.03	1.42	2.66	0.84	7.97	...	0.22	11.69	85.5	Kohala
Kilauea	7.40	2.60	26.20	...	4.00	40.20	0.37	0.13	1.31	...	0.20	2.01	3.76	1.37	13.35	...	2.04	20.52	76.9	Kilauea
Waianae	8.40	2.80	25.00	...	6.40	42.60	0.42	0.14	1.25	...	0.32	2.13	3.03	0.99	9.01	...	2.31	15.34	83.79	Waianae
Kaeleku	11.40	3.20	24.20	...	5.60	44.40	0.57	0.16	1.21	...	0.28	2.22	5.09	1.41	10.75	...	2.46	19.71	80.98	Kaeleku
Union Mill	15.00	2.60	....	...	21.00	38.60	0.75	0.13	...	...	1.05	1.93	6.50	1.09	....	...	9.10	16.69	85.60	Union Mill
Halawa	14.20	2.40	....	...	20.80	37.40	0.71	0.12	...	...	1.04	1.87	6.18	1.04	....	...	8.97	16.19	84.72	Halawa
Niulii	12.00	2.80	....	...	22.60	37.40	0.60	0.14	...	...	1.13	1.87	5.76	1.29	....	...	10.80	17.85	81.54	Niulii
Waimea	8.20	1.20	....	...	36.60	46.00	0.41	0.06	...	...	1.83	2.30	3.09	0.44	....	...	13.82	17.35	85.45	Waimea
Olowalu	6.60	0.80	25.60	...	22.00	55.00	0.33	0.04	1.28	...	1.10	2.75	2.45	0.29	9.55	...	8.17	20.46	82.61	Olowalu

Sugar Prices

96° Centrifugals for the Period Sept. 17 to Dec. 12, 1928.

Date		Per Pound	Per Ton	Remarks
Sept.	17, 1928	4.02	80.40	Cubas.
"	18	3.99	79.80	Cubas.
"	19	3.96	79.20	Cubas.
"	20	3.91	78.20	Cubas, 3.93; St. Croix, 3.89.
"	21	3.96	79.20	Cubas, 3.96, 3.99; Porto Ricos, 3.93.
"	24	3.99	79.80	Cubas.
"	25	3.93	78.60	Cubas.
"	26	3.945	78.90	Cubas, 3.93, 3.96.
"	27	3.96	79.20	Cubas.
"	28	3.945	78.90	Cubas, 3.96, 3.93.
Oct.	1	3.93	78.60	Cubas.
"	2	3.90	78.00	Cubas, 3.89, 3.91.
"	3	3.89	77.80	Cubas.
"	8	3.945	78.90	Cubas, 3.93, 3.96.
"	9	3.93	78.60	Cubas.
"	10	3.9467	78.93	Cubas, 3.93, 3.95, 3.96.
"	11	3.93	78.60	Cubas.
"	18	3.96	79.20	Cubas.
"	19	3.93	78.60	Cubas.
"	26	3.895	77.90	Cubas.
"	29	3.86	77.20	Cubas.
"	30	3.83	76.60	Cubas.
"	31	3.80	76.00	Cubas.
Nov.	1	3.77	75.40	Cubas.
"	8	3.83	76.60	Cubas.
"	9	3.91	78.20	Cubas, 3.89, 3.93.
"	10	3.89	77.80	Cubas.
"	12	3.9267	78.53	Cubas, 3.96, 3.89, 3.93.
"	13	3.83	76.60	Cubas.
"	19	3.89	77.80	Cubas.
"	21	3.9333	78.67	Cubas, 3.96, 3.93, 3.91.
"	22	3.89	77.80	Cubas.
"	23	3.90	78.00	Cubas.
"	26	3.94	78.80	Cubas, 3.96, 3.92.
"	27	3.96	79.20	Cubas.
Dec.	5	3.93	78.60	Porto Ricos.
"	8	3.89	77.80	Porto Ricos.
"	11	3.93	78.60	Cubas.
"	12	3.945	78.90	Cubas, 3.93, 3.96.